THE NEW BASIC SCIENCE

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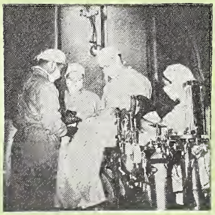
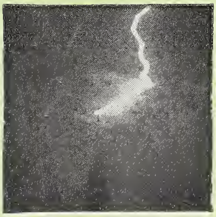


SCIENCE

J. DARRELL BARNARD
& LON EDWARDS



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About the authors—

J. DARRELL BARNARD Chairman, Department of Science Education, School of Education, New York University, New York City, *Formerly* Supervising Teacher of Science, College High School, Colorado State College of Education

LON EDWARDS Chairman, Science Department, Danbury State Teachers College, Danbury, Conn., *Formerly* Supervising Teacher of Science, College High School, Colorado State College of Education

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LISTEN TO THE SOUND . . .

LISTEN to the sound drifting in through the window. Is it the hum of traffic or the rustle of leaves? Is it the drone of an airplane overhead or the staccato clatter of a drill biting into the pavement? Is it the whir of a lawn mower cutting the grass or the whish of the water sprinklers cleaning the streets? Whatever it is—do you realize that all of them have a connection, one way or another, with science? Either they have been made possible by science, or science has changed them so that they are more useful. They may have given scientists who studied them a clue to something else. They may have been made quieter or more powerful or easier to use by scientists. For science reaches into your life in unexpected ways, and it may change your future drastically.

Why does science affect you, you may ask. And how? And what is your place in the picture of science? Those are good questions. This book, *The New Basic Science,* helps you to answer them yourself.

That, indeed, is one of the keys to this book. It *helps you* to "do it yourself." Although it does give you the fascinating stories of how scientists have made their discoveries, and how science has been used to improve the lives of everyone, it also—and above all—gives you a chance to do problem-solving yourself, using the techniques of the scientist in a great number of different situations. Nor is the problem-solving limited to the science classroom or the laboratory. It is used in evaluating other people's activities. The book teaches you the techniques of science which you can use in a continually growing number of situations.

How does *The New Basic Science* do this? Take a look at the **Table of Contents.** You will notice that the scope of science is wide—from the earth beneath you to the heavens above, from the energy of the sun to atomic energy, from weather and climate to caring for living things (including yourself), from the use of machines to do a variety of things to the transportation and communication which is such a vital part of our world today. You will see, moreover, that every chapter is divided into problems, and you will find that the text helps you to work out the answers to those problems, just as scientists do.

But *The New Basic Science* does more than that. It gives you a chance to **apply the same methods to new situations**—the things around you. From Unit 1 you learn how to use science in your everyday life: shopping for a camera, deciding on your courses, improving your tennis game. In such problems, just as much as in the laboratory, you learn to look for reliable explanations, analyze the problem so that you can consider the things which are really pertinent to it. You need to know where and how to find information which bears on the problem, and then plan ways to test the strength of the evidence you gather. And then, you must generalize from that information to **summarize** your conclusions.

Perhaps you don't know what a generalization is. Yet you hear them every day; you probably use them yourself. Your study of the problems in *The New Basic Science* will help you to understand science generalizations which, in turn, you will be able to apply to other problems that interest you. The book, as it takes up each problem, works it out *with* you (not *for* you). At the end of each problem is a summary of all the important **generalizations** used in the problem. Then, to help you check your understanding, comes a **self-test**. Also, the book gives you a chance to perform **experiments and demonstrations** yourself. To test some of the generalizations you need only the simplest equipment at your finger tips; for others you use equipment in a laboratory. But you have the satisfaction of *doing it yourself*, and learning a great deal in the process.

Then, at chapter-ends, *The New Basic Science* provides all kinds of other **activities** and **situations** in which you can put into practice the techniques you have learned in the various problems. You can plan and set up your own experiments; you can apply your knowledge of the methods of science to many so-called non-scientific situations. You can match generalizations to facts or pick the scientific word that describes a process. You can read from the lists of books at unit ends about any special phase of science that has stimulated your special interest.

The book helps you to do all this. Words in new scientific vocabulary are *italicized* the first time they occur. These are defined in the same sentence, or near by. When you next meet the word, it should be a part of your vocabulary. But in case you want to review its meaning, you can turn to the **Index**, where you will find listed the pages where the subject occurs. Also the pronouncing **Glossary** helps you to define further some of the more difficult words.

Furthermore, don't neglect the pictures. Each **illustration** in this book, with its caption, has been included because it tells something essential about the problem. It may illustrate one of the generalizations; it may show a practical application of that generalization to a concrete situation. It may show the actual construction of a device which science has produced to adapt our environment to our needs. The **drawings** shown with the experiments, demonstrations, and observations show you how to set up the necessary equipment—without taking away the satisfaction of discovery by giving away the result of the activity.

After going into the many problems presented in *The New Basic Science,* you will realize just what a powerful instrument science is in our lives. But you will want to be sure that the changes it is making in adjusting our environment to make our living better—and the way it is putting the enormous power to work—are all being properly and wisely handled. That is one of the vital parts of the study of science. The conservation of all our resources, which includes wise use of them, must be of immediate concern to everyone. The background for this kind of judgment, the information necessary for a wise evaluation, is also here in *The New Basic Science.*

The New Basic Science helps you in your study of science. It also points the way to the future. For science is a *continuing* process. Just as each unit in this book is built on the foundation of knowledge gained from the preceding unit, so science builds on today's achievements for its discoveries tomorrow. You are a part of that tomorrow.

Cushing

By careful and systematic observations scientists collect information which is then studied and used in solving their problems.

unit 1 SCIENCE IN EVERYDAY LIFE

IT'S fun!" "It's tough!" "It's boring!" "It's interesting!" These are some of the statements young people have made about "science" in their daily school lives. Let's face it. Some young people have liked their science courses very much, while others have disliked them equally as much. It is possible that those who dislike science have never really understood what it is. They may not have seen clearly how science has affected practically everything we do nor how it can be used to make our lives better. It is for these reasons that we are beginning this book with a unit to help you get a better understanding of what science really is.

It is interesting that more people today than ever before are reading about science, talking about science, yes, even guessing what new ideas the scientists will discover next and what new gadgets will be produced as a result of their discoveries. Sometimes this guessing gets pretty wild, as we have seen and read in some science fiction.

Science is important in our lives because the people who work at it, the scientists, have given us many things which add greatly to the comfort and joy of living; sometimes they even keep us alive. Science is important because of the vast amount of knowledge that has accumulated from scientific discoveries made over the past several hundred years. With this knowledge we can today understand the world in which we live better than has ever before been possible. Then, too, science is important because scientists use methods to solve problems which anyone can use to solve problems, whether they occur in the laboratory or not.

But only to tell you that science is important in our everyday lives does not and really should not convince you. In the true spirit of science, let's examine together the evidence in this unit and see if it shows clearly the importance of science in our lives.

General Electric Company

This scientist is demonstrating the magic of science. By holding a match in front of a special tube, called a phototube, he causes an electric current to operate a switch, thus lighting an electric lamp.

chapter 1 MEANING OF SCIENCE

A LITTLE boy once told his teacher that he would like to draw a cow but that he didn't know where to begin. Knowing where to begin is an important step in performing any task you may have to do. It is especially important in beginning a study of science. If this is your first course in science, you are probably eager to find out what science is. If you have taken science courses in earlier grades, you may already have begun to develop some ideas about the meaning of science. This chapter should help you to obtain a better understanding of what science means to some people who are not scientists and what it means to the scientists.

Bloom from Monkmeyer

In sports, such as wrestling, the contestant who uses methods that have been proved successful is often said to be scientific in the way he plays the game. People who use the term scientific in this way are using it to mean a way of doing something.

PROBLEM 1. What does science mean to people who are not scientists?

IDEAS ABOUT SCIENCE

Science as a way of doing something. In trying to find out what the term *science* means to people who are not scientists, we might consider how boys and girls use the term. Suppose, for example, that you are discussing a recent basketball victory. Your team worked the ball down the court in a series of perfectly-timed, exact passes and made the field goal that turned the score in your favor. The successful play brought the spectators to their feet cheering. After things had quieted down, one of your classmates may have remarked, "Boy! they used science in that play."

At some time one of your friends may have shown little judgment in selecting a suit of clothes or a dress. Perhaps the color was not right, or the style was not suited to the person's figure, or the material was not of good quality, or something else was obviously wrong with the garment. As you studied the situation thoughtfully you wondered why your friend had not been more "scientific" in making the selection.

It seems, therefore, that there is a science of playing basketball and a science of buying clothes. We have all used the term *science* with this meaning when we have tried to describe a successful way of doing something.

Science as truth or authority. The terms *science* and *scientific* are commonly used in advertisements to influence readers to buy a certain product. "Grow hair the scientific way" reads one advertisement for a hair tonic. Another advertisement claims that a product is superior because it has been "scientifically tested." Still another states that the product is a new "scientific discovery." You can probably think of several similar advertisements that you have seen lately. Perhaps some of them made you want to buy the article advertised.

Advertisers know that their readers accept science as a basis for authority or truth, and for good reasons. By the use of science, many products have been developed during the past fifty years to make our lives safer and more comfortable. Such achievements have won our respect. Through the use of science, scientists have time after time made possible many things which were long thought impossible. For example, not so very long ago people believed it impossible for men to fly in a machine. Today, through discoveries made by scientists, man can fly in planes that move faster than the speed of sound, and he can operate pilotless planes by radio controls.

In medicine, too, scientists have achieved what had been considered impossible. At one time people thought that when certain disease-producing germs had entered the human body, little or nothing could be done to destroy them. They believed that if the body itself were not able to destroy the germs or overcome the poisons produced by them, death would result. The doctor could only assist the body in its natural fight against these deadly invaders. But one after another, *quinine, sulfanilamide, penicillin,* and many other drugs have been discovered or prepared. They work like "magic bullets" in controlling certain disease germs within the body.

Many other important discoveries have been made and are continually being made. Because of the repeated successes of men using science, science has become an authority to many people.

Science as a kind of magic. Have you ever attended a magician's show? What makes it so much fun? Things which seem impossible happen before your eyes. You watch the magician carefully as he pulls articles out of the air and you try to guess how he does it. You believe there is an explanation for every trick, but you just can't understand it. Finally you give up and accept the magician's tricks as magic.

You may also have attended a science show where some of the marvels of science were demonstrated. At one science show the demonstrator asked a member of the audience to hold an unattached light bulb. Then by turning on something on the stage he caused the bulb to light. Another demonstration is shown in the picture on page 3. Nothing a magician could do is more exciting than such demonstrations at a science show. People who do not understand how science demonstrations work may regard them as a kind of magic.

Science as a fearful force. Both the atomic bomb and the hydrogen bomb were brought about by man using science. We are all afraid of the terrible human destruction that would result from the use of these bombs in another

U. S. Air Force

Cloud formed by a hydrogen bomb. Such pictures are the fearful symbol of the destructive force of atomic and hydrogen bombs.

war. Since these destructive weapons were made with science, many people have come to fear science as a force over which man has no control and that one of these days will surely destroy him. They do not realize that science is man-made and if people will learn how to control themselves, they should have no fear of controlling science so that its discoveries may be used for good among all people of the world.

Science as information or knowledge. Probably the most common idea about science is that it is organized knowledge to be studied. If you ask some of your older friends what the term *science* means to them, they will probably name *physics, biology,* or some other science subjects which they studied when they were in school; that is, *science* means a special kind of information or knowledge organized into definite subjects. Biology is the knowledge of living things. Physics is the knowledge of natural forces and energy. To many people, science means an organization of the facts which man has discovered about his environment.

SUMMARY

Because of the nature of science and the number of ways in which it is used, there are many ideas about its meaning. We have seen that the term *science* is commonly used with five different meanings: (1) Science represents facts and is therefore an authority. (2) It is an exact or effective way of doing something. (3) It resembles magic because it seems to perform wonders. (4) It is a force to be feared because of the destructive ways some of its discoveries have been used. (5) It is a special kind of organized knowledge to be studied.

TEST YOURSELF

In studying science or any other subject in school, it is important to check yourself frequently to make sure that you understand what you have read. Exercises have been placed at the end of each problem in this book, to help you determine how well you understand the material covered in the problem. Answers must be written for each of the items or questions in the exercise, but **you should *not* write the answers**

in your book. Instead prepare an answer sheet with as many numbers as there are items in the exercise.

The word *science* or *scientific* is used in each of the following items. Indicate the meaning of each such use by writing one of the letters **a** to **d** after the appropriate number on your answer sheet. If *science* or *scientific* means a way of doing something, write the letter **a;** if it means an authority, write **b;** if it means a kind of magic, write **c;** if it means something to be feared, write **d;** if it means knowledge or information, write **e.**

1. It is often said that a science of business is badly needed.
2. John says his new science course, chemistry, is interesting.
3. The "Magic Eye" is a scientific device used on many radios.
4. Radar is often said to be one of the scientific marvels developed during World War II.
5. Biology, a science course taught in high school, deals with living things.
6. Mary used a certain toothpaste because she had read that it contained a new scientific discovery.
7. Food production in the United States has been increased through scientific research.
8. There should be greater control over the use of science.

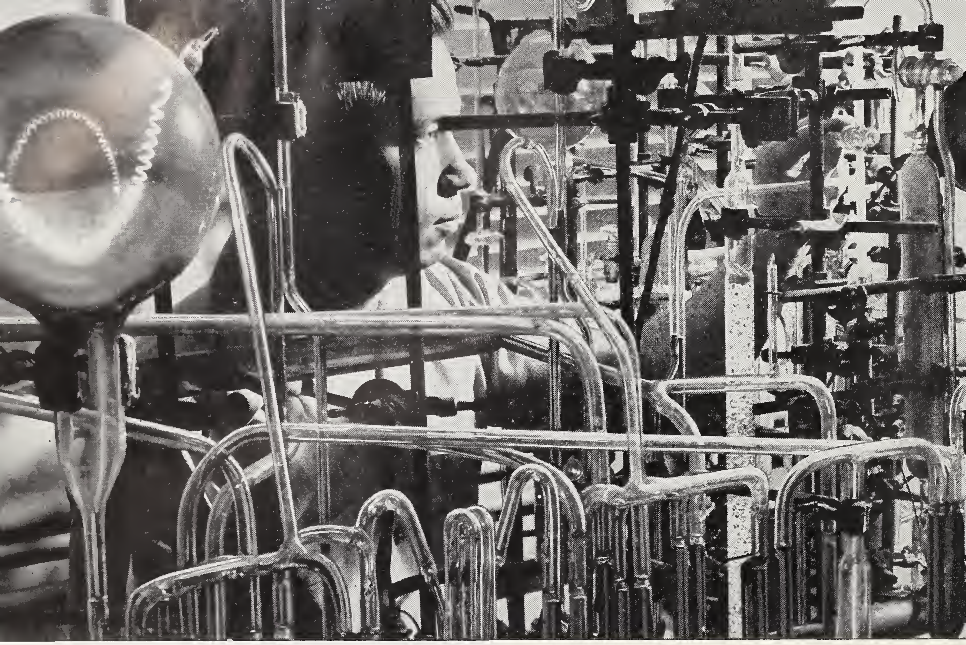
PROBLEM 2. What does science mean to the scientist?

EXPERTS IN PROBLEM SOLVING

Methods of the scientist. You may have imagined that a scientist is a queer person who spends most of his time in a gloomy *laboratory* working with a roomful of complicated apparatus, and that he is not very much concerned with everyday things. Nothing could be farther from the truth. Scientists are very much like the rest of us. When they were growing up they were like other boys and girls who are interested in the things happening around them, but perhaps they wanted to find out how and why these things happened. They wanted to know what makes plants grow, what brings about the colors of the sunset, what causes the weather to change, why there are electrical storms, and they sought the answers to many other questions. In school they took the courses which helped them find these answers.

As they continued their studies they became interested in problems which had not yet been solved. To try to find the answers to some of these unsolved problems, they learned methods of thinking and working called *scientific methods.* To the scientist, *science* means a method of solving a problem as well as the information he obtains in solving it. In order to understand the scientific methods of problem-solving, let us observe the scientist at work.

Scientists in industry. Scientists are employed by automobile manufacturers, food processors, manufacturers of electrical equipment, drug manufacturers, and many other industrial enterprises to solve many problems, such as: How can products of better quality be manufactured? How can new sources of raw materials be used? How can cheaper methods of production be developed? Television, antiknock gasoline, glass cloth, nylon hosiery, syn-



Standard Oil Co. (N.J.), photo by Corsini

In well-equipped laboratories industrial scientists study ways in which their companies can produce better goods and services for their customers. Such laboratories are costly, but results are valuable.

thetic rubber, and hundreds of other products have been created for us by industrial scientists.

Scientists in government. Scientists in various government agencies work on such problems as: How can diseases be controlled? How can soil be used most effectively? How can better food plants be developed? Information which government scientists have obtained in working on these problems has improved living conditions throughout the United States. These scientists have helped to control diseases. They have developed better varieties of food plants and effective methods of using soil. They have helped Americans to be healthier and better fed than they used to be.

Scientists are also needed to help build a strong national defense. They are needed to solve such problems as: How can we build stronger and faster airplanes? How can humans fly at high altitudes and at speeds faster than sound travels? How can we use radar to protect us from enemy attacks by airplane? How can atomic energy be used in different kinds of weapons? How can civilians protect themselves from atomic bomb attacks? How can we protect ourselves from germ warfare? It is interesting to note that science is used not only to build new weapons of destruction, but also to find ways of protecting us from such weapons.

Scientists in educational institutions. Many of the outstanding scientists in the United States are associated with universities and colleges. One of their important duties is to help educate young men and women who may become our future scientists. By their work on special problems, they add to our knowledge of the world in which we live. Much of the basic knowledge about atomic energy, for example, was discovered by scientists in the laboratories of universities and colleges. Both private and public institutions spend millions of dollars every year in using science to solve problems. Like industrial concerns and government agencies, these institutions operate large, well-equipped laboratories where scientists can work to solve many different problems.

METHODS USED BY SCIENTISTS

In order to obtain dependable, accurate solutions to the problems they undertake to solve, scientists must be careful, patient, and efficient workers. A review of the way in which scientists have solved some important problems will help you understand how the methods are used.

Pasteur's use of the experimental method. Less than a hundred years ago Louis Pasteur, a French chemist, became interested in the prevention of diseases in animals. At that time in southern France large numbers of sheep were dying each year of a disease called *anthrax*. Robert Koch, a German scientist, had already discovered the *bacterium* (tiny one-celled plant) that causes this disease. Pasteur believed that weakened anthrax bacteria (plural of bacterium) injected into the body of a sheep over a period of time would prevent the sheep from getting the disease. In order to test his belief, he decided to try it out with sheep. At first he injected the animals with a very small amount of weakened anthrax bacteria. As he continued the injections, he gradually increased the amount of bacteria. Finally he injected an amount sufficient to kill an untreated sheep, but, as Pasteur had expected, the sheep was not affected. He proved to himself that the injections had protected the sheep against anthrax.

When farmers learned of Pasteur's successful experiment, they begged Pasteur to save their sheep from anthrax, but the *veterinarians* (men who treat the diseases or injuries of animals) ridiculed Pasteur's idea. What did a chemist who was not even a doctor know about animal diseases? A public demonstration was arranged to determine whether or not Pasteur's treatment was effective.

Robert Koch at work in his laboratory in Kimberley, South Africa, where he was called in 1897 to find a way to control a cattle disease.

Illustrated London News, 1897

The experiment was begun on May 5, 1881. Forty-eight sheep were divided into two pens. The sheep in pen 1 were injected with weakened anthrax bacteria at regular intervals; those in pen 2 were not treated. About a month later a deadly amount of the bacteria was given to the sheep in both pens. The results were awaited with anxiety and excitement. Would the sheep that had been treated survive? Two days later none of the sheep in pen 1 had developed anthrax; all except two in pen 2 had died, and those two died later. These results proved, as had Pasteur's earlier experiment, that sheep could be protected from anthrax.

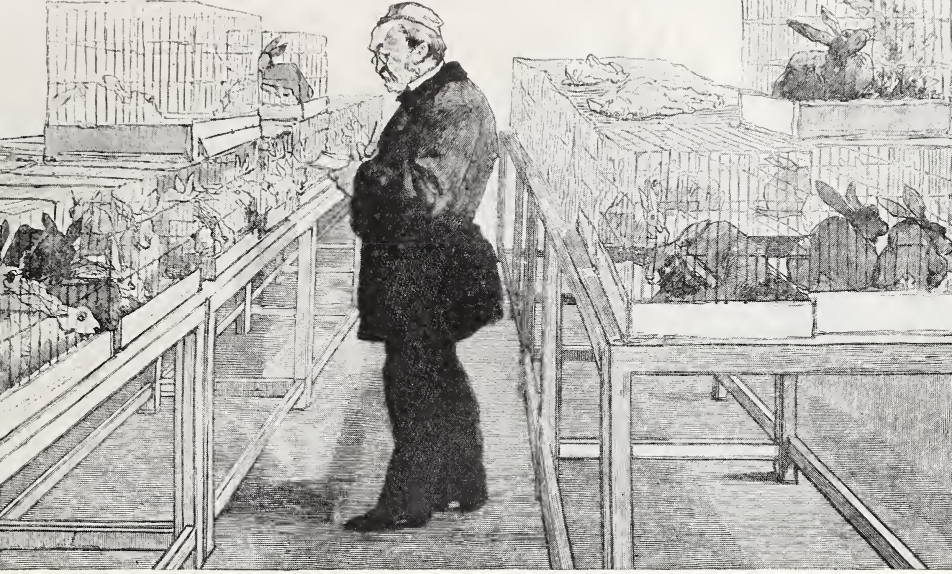
Pasteur began with a belief that sheep could be protected from anthrax by a series of injections with bacteria. Such a belief is called a *hypothesis*. After Pasteur had formed his hypothesis he conducted experiments and made observations to test it. The results of his experiments proved that the hypothesis was correct. Pasteur had used the experimental method.

Penicillin produced by the methods of science. Another example of how scientists work is the development of penicillin. In 1929 Dr. Alexander Fleming was studying a certain type of disease-producing bacteria in the laboratory at St. Mary's Hospital in London. He was growing the bacteria on food material in special dishes, covered to prevent other types of tiny plants present in the air from entering them. But it happened that in one of the dishes left uncovered a mold known as *Penicillium* soon began to grow on the food material. Dr. Fleming noted that wherever the mold had grown in the dish, the bacteria had disappeared. He immediately became interested in finding out what effect the mold had on the bacteria.

Since Dr. Fleming was a scientist, several problems came to his mind: What substance did the Penicillium mold produce that destroyed the bacteria? Could this substance be obtained in pure form? Could it be used to destroy bacteria in the bodies of animals without harming the animals? In attempting to solve his problems, Dr. Fleming grew large quantities of the Penicillium mold in a special broth. After the mold had grown, he found that the broth contained a substance which would destroy certain types of bacteria. Since the substance was produced by Penicillium, he named it *penicillin*. He injected the broth containing penicillin into rabbits and found that it did not harm them.

Dr. Fleming made many attempts to obtain pure penicillin from the broth, but he was not successful. Finally, believing it was not possible to obtain penicillin in pure form without destroying its effects upon bacteria, he discontinued his work.

About ten years later two other English scientists, Dr. Florey and Dr. Chain, began working on Dr. Fleming's original problem of obtaining pure penicillin. At that time England was at war, and English scientists were encouraged to work on problems that would save the lives of English soldiers. By 1941 Dr. Florey and Dr. Chain had succeeded in obtaining penicillin in pure form. They had also tested its effect on human beings and had found that a number of human diseases could be successfully treated with it. Other scientists helped develop methods for producing penicillin in large quantities. By 1945 enough of it was being pro-



Illustrated London News, 1884

After the death from hydrophobia of a five-year-old child in 1880, Pasteur began experiments with rabbits, monkeys, and dogs which later led to successful treatment for this dreaded disease. Here he is shown observing the rabbits used in his experiments and carefully recording his observations.

duced so that it could be used in hospitals and by doctors throughout this country.

Scientists continued to experiment with penicillin. In 1946 Dr. Molitor and Dr. Moore reported that penicillin had definite limitations. Dr. Molitor found that certain bacteria seemed to develop a resistance to it. Dr. Moore discovered that penicillin is not one pure substance but a mixture of several different substances, not all of which are equally effective in controlling harmful bacteria.

The story of the discovery and use of penicillin shows that conclusions to problems are not always accepted as final. Scientists continue to question and test their conclusions, accepting no conclusion as final until all available evidence supports it.

Characteristics of scientists at work. In order to be good problem-solvers, scientists must be able to recognize important problems. They must form hypotheses and devise experiments to test each hypothesis. After organizing the information collected from their experiments they must formulate their conclusions based only upon tested information.

A scientist has certain attitudes or beliefs which make his method of solving problems scientific. Below are descriptions of attitude of scientists:

1. Scientists are curious. They ask questions. If the cause of some event is not known, they want to find out what it is. Dr. Fleming discovered penicillin because he wanted to find out why the Penicillium mold affected the bacteria.

2. Scientists wait to make a decision until they have collected all important facts. Those scientists who are working with penicillin are not at all willing to make a final statement regarding its effectiveness in treating some diseases. They believe that there are still many important facts to be discovered about penicillin.

3. Scientists select their sources of information with great care. They want to be sure they are using the best source. Whenever possible, scientists use carefully conducted experiments to obtain the facts needed in solving their problems. When Dr. Fleming discovered the effect of mold on the one dish of bacteria, he devised experiments to test the mold on many other dishes of bacteria. He wanted to be sure that it was the mold and not something else that caused the bacteria to disappear.

4. Scientists select only the information applying to the problem upon which they are working. When Dr. Florey and Dr. Chain were working on the problem of obtaining pure penicillin, they probably discovered many interesting facts which did not concern their problem directly. They selected, however, only facts related to their problem.

5. Scientists are willing to change their points of view when additional reliable information is obtained. Some scientific investigators had previously shown that penicillin would control certain bacteria. When Dr. Molitor later showed that these bacteria might become resistant to penicillin, earlier investigators accepted his findings because they were based on carefully conducted experiments.

SUMMARY

To the scientist, science is not just a systematic body of knowledge, but is also the application of careful methods to the solving of problems. In using these methods, scientists exhibit certain attitudes which make the methods effective.

TEST YOURSELF

In this exercise you are to select the ending which will make each statement most accurate and write its letter in the proper place on the answer sheet. **Do not write in this book.**

1. When Pasteur began his work with sheep he had an idea that sheep could be protected from anthrax by injections of weakened bacteria. Such an idea is known as (a) a hypothesis; (b) an experiment; (c) a conclusion; (d) a fact.
2. Pasteur proved that his idea for protecting sheep from anthrax would work by (a) arguing with the veterinarians; (b) persuading the farmers to try it; (c) experimenting with sheep; (d) watching sheep die from the disease.
3. A conclusion may be accepted as final if (a) it has been printed in a magazine or newspaper; (b) it is based upon a single experiment; (c) it has been criticized by many people; (d) the evidence from many experiments support it.
4. Scientists are valuable in industry, government agencies, and educational institutions because they (a) are good speakers; (b) are very different from other people; (c) work for less money than other people; (d) are expert problem-solvers.

CHAPTER ACTIVITIES

REVIEW YOUR UNDERSTANDING

Throughout this book, exercises have been placed at the end of each chapter to help you check your understanding of the chapter and to give you practice in applying science in your everyday living. Answers to each of the following items should be written on a separate answer sheet. **Do not write in this book.**

1. Which of these meanings of science would be least acceptable to a scientist?
   - a. An authority
   - b. A way of doing something
   - c. Magic
   - d. Knowledge or information
   - e. Something to fear

2. Which of these statements best describes the veterinarians' attitude toward Pasteur's work with sheep when they first heard about it? You may use more than one.
   - a. They were willing to accept Pasteur's conclusions provided he had facts to support them.
   - b. They were anxious to learn how Pasteur had carried out his work.
   - c. They believed a chemist could know very little about disease.
   - d. They repeated Pasteur's experiment.

3. If Dr. Fleming had not been a scientist, he might have considered the mold which accidentally got into the bacteria dishes as merely a nuisance that spoiled his work. What attitude did Dr. Fleming show when he recognized a new problem in this incident?

4. From each pair of traits listed below, select one which best describes a person using the methods of science.

a. Continually questions what he sees and does   b. Accepts everything without questioning

a. Uses only facts which support his own ideas   b. Uses all facts which have a bearing upon his problem

a. Uses experiments to test his own conclusions   b. Uses experiments only when his conclusions are questioned

a. Whenever solving a problem, carefully examines any new problems that arise   b. Whenever solving a problem, disregards any new problems which may arise

a. Makes judgments with little evidence   b. Weighs evidence carefully before making any judgments

a. Uses information regardless of its source.   b. Uses only tested or reliable information.

Reeves from Monkmeyer

Young people can use science to help solve a number of personal problems such as "How can I improve my appearance?"

chapter 2 USING THE METHODS OF SCIENCE

WHO benefits from the use of science? From the illustrations discussed in Chapter 1, it would seem that all of us do. We benefit whenever the methods of science are used to solve problems dealing with the maintenance of health, the production and preservation of foods, the construction of our homes, and the improvement in communication and transportation. Not only have our ways of living changed, but people themselves have also been changed. Today we are better able to explain happenings which used to be considered strange and mysterious. Although there is still need for improvement, we are now generally less fearful of some things than our fathers and grandfathers were. We should also be more scientific in our thinking than our ancestors were.

This chapter should help you to understand how the use of scientific methods has improved living conditions and changed people. It should also help you to make better use of the methods of science in everyday living.

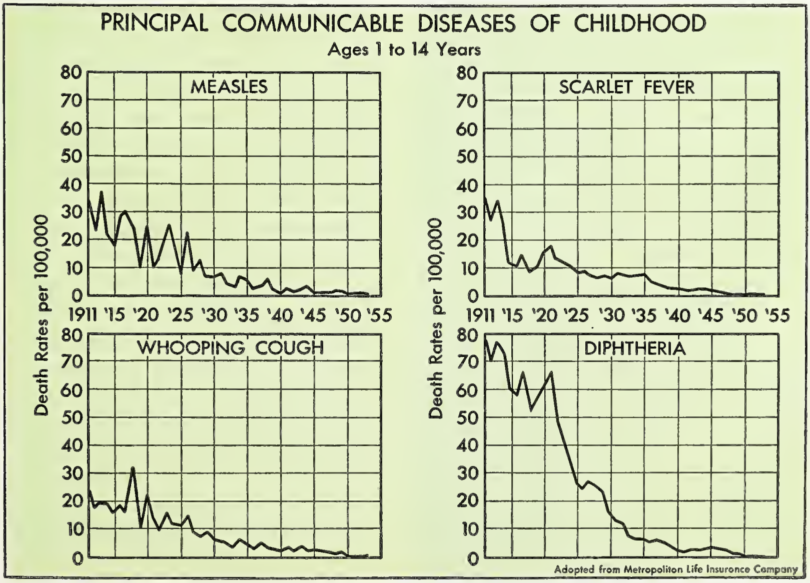
PROBLEM 1. How have our ways of living been changed by the use of scientific methods?

IMPROVEMENTS FROM SCIENCE

Better control of disease. If you had been born two hundred years ago, you would have had about three chances in four of living to be one year old. In other words, in those days about one out of four babies died before reaching its first birthday. Suppose you had been one of the stronger little fellows and had lived through that first year. Very likely before you were six years old, you would have had smallpox, and by the time you reached the age of twelve, you would undoubtedly have had measles, whooping cough, scarlet fever, and diphtheria. Even then your battle for life was not over. Yellow fever, malaria, typhus, cholera, typhoid fever, and even influenza, once started, spread through a community. Life was most uncertain. A person who lived to be more than thirty years of age was indeed fortunate.

Today babies are born in hospitals where they are unlikely to get a disease. Young people are treated to protect them against smallpox, diphtheria, and typhoid fever. Today a person can expect to live to be almost seventy years old. These changes have been made possible by use of scientific methods to solve such problems as the causes of disease and its prevention.

Better sanitary conditions. It is difficult to imagine what sanitary conditions in some of our larger cities were like only one hundred years ago. Into the narrow, unpaved, and poorly drained city streets, household garbage


PRINCIPAL COMMUNICABLE DISEASES OF CHILDHOOD

Ages 1 to 14 Years

Adapted from Metropolitan Life Insurance Company and other refuse were thrown. Outdoor toilets were common, many of them situated where human wastes drained into wells from which people obtained drinking water.

Today our city streets are paved and well drained, and they are cleaned regularly. Sewage from all sections of a city is carried through sealed pipes to disposal plants. Through the use of scientific methods it has been demonstrated that unsanitary conditions cause the spread of diseases like typhoid fever, cholera, and dysentery.

A century ago it was common practice in many cities to buy water by the bucketful for household use. Often it came from sources that contained disease-producing germs.

Towns and cities today have water systems that usually provide water pure enough for household use. One of the most important problems in the growth of cities has been to provide sufficient pure water to meet the many needs of an increasing population. Many cities have found it necessary to build huge pipe lines to bring water from sources several hundred miles away.

More food and better food. Changes have taken place, too, in our eating habits. Through the use of science, we have learned that it is healthful to eat many kinds of food, and we have learned how to provide ourselves with a variety of foods throughout the year. People who lived a century ago probably enjoyed eating as much as we do today, but they could not have as many different kinds of food. Most of their foods had to be produced on their own farms or in their own gardens. Thrifty housewives preserved their home-grown vegetables and fruits by canning, pickling, or drying them for use during the cold weather. Meats were preserved by salting and drying or by freezing when the weather was cold enough.

Today people in many parts of the world can obtain some fresh fruits, meats, and vegetables throughout the year. By the quick-freeze method, vegetables, fruits, sea foods, and meats of various kinds can be preserved so that they are both nutritious and enjoyable. Modern methods of selecting, grading, and processing foods have removed the risk or danger of poisoning from canned foods.

Our eating habits are not the only things in our lives changed by the use of science. We have also used science to learn more about the processes and materials in our surroundings and about the methods of controlling them. As a result, we have been able to improve our ways of building houses, our methods of communication and transportation, and even the way we spend our leisure time.

Better attitudes. By an *attitude* we mean the way we feel toward some idea or some event. If a person feels that wearing some kind of charm will prevent him from having bad luck, he will wear the charm, and will feel uncomfortable without it. Feelings which involve fears such as this are called *superstitions*. Superstitious people believe in signs of good or bad luck, and their lives are greatly influenced by such signs.

Superstitious beliefs are being overcome by using scientific methods to show that there is no sound basis for them. Few people today believe that diseases are caused by evil spirits. Most people no longer fear black cats, broken mirrors, and the number 13. Though *astrology* and fortunetelling are still practiced, they do not influence the lives of as many people as they once did.

By scientific methods it has been shown that ideas are not necessarily true because they have been believed for a long time. The discoveries of scientists have encouraged people to be more willing to look for new truths rather than to assume that what has been considered true will always be true.

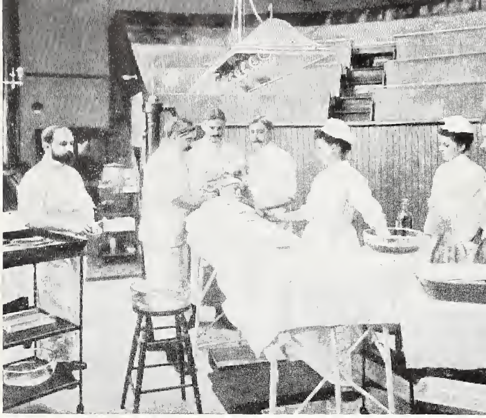
SUMMARY

By using science in controlling disease, improving his surroundings, and obtaining a greater variety of good food, man has improved his health and has increased the number of years he may expect to live. The lives of fewer people are controlled by superstitious beliefs, and people are less fearful of their environment than they used to be.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet; if it is false, write *false* on your answer sheet. **Do not write in this book.**

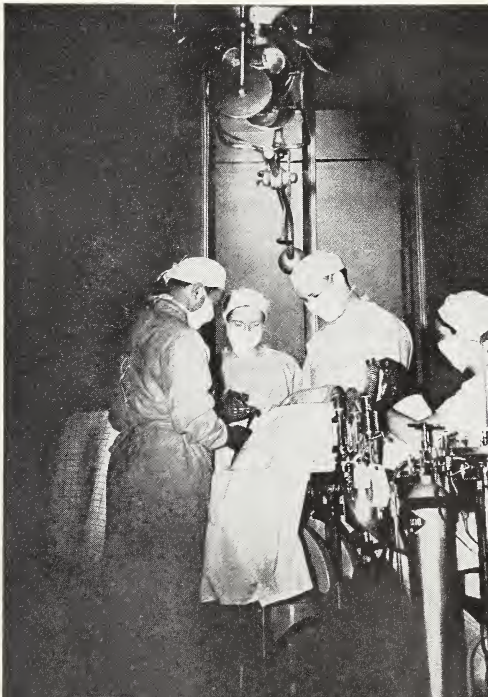
1. The death rate among babies is lower than it was a hundred years ago.
2. Many diseases, such as smallpox and diphtheria, are unknown today.
3. Many food problems have been solved through the use of scientific methods.
4. Astrology and fortunetelling are not practiced in the United States.
5. Ideas which have been believed by people for a long time are always true.
6. Obtaining enough water is no longer a problem in cities.



New York Hospital

An operating room in a fine hospital about 80 years ago (above). The way the room was constructed, and the furniture, fixtures, and dress of the doctors made it difficult to keep conditions sanitary. Science has been used to improve sanitary conditions in hospitals. Below is an operating room in a modern hospital. Walls, floor and equipment can be cleaned easily and thoroughly. Germ-free rubber gloves, masks, and gowns are worn by the doctors and nurses.

United Hospital Fund



PROBLEM 2. How can our method of solving personal problems be more scientific?

PERSONAL PROBLEM SOLVING

Solving personal problems. You know what the problems of boys and girls of your own age are. Probably most of them are personal problems: How can I improve my appearance? How can I become popular? How can I earn my spending money? How should I select my high-school courses? Such problems are not taken to the science laboratory to be solved. Microscopes, test tubes, and other laboratory equipment are not needed. Although they might not even sound like science problems, scientific methods should be of some help to us in solving them. A comparison of the methods used by two boys in solving a personal problem might help us understand better how scientific methods can be applied to many problems of our everyday life.

Upon entering high school, two boys were confronted with the same problem: "How should I select my high-school courses?" The first boy, Robert, at the beginning of the school year asked his friends which subjects they liked best or thought would be easy. He checked with other boys to find out which courses they were planning to take, and then enrolled for courses they recommended. When he found that some of the courses required a good deal of work, he lost interest in them. As soon as possible, he dropped them and enrolled for others which he thought he might like better. Throughout his years in high school, he selected courses in this manner, with no clear idea of why he was taking any of them. His only concern was to graduate from high school.

The other boy, James, some time before school started, attempted to find out what a high-school education could mean to him. He discussed the matter with the principal of the high school and also asked the opinions of friends who had graduated from high school. He concluded that his high-school education could prepare him for college work and a profession or for a particular occupation or trade. Before selecting his courses, he would have to decide what kind of work he hoped to do after finishing school. He had always been interested in *mechanics.* Should he become a *mechanical engineer,* or should he enter a mechanical trade after completing high school? Who could help him make his decision?

Recalling that one of his teachers had talked to his class on the subject of vocations, James consulted this teacher. He learned that if he intended to become an engineer, he would have to study highly technical subjects requiring special ability, whereas to be successful in mechanical trades he would have to develop special skills. The tests he had taken in junior high school showed that he had the necessary ability for both kinds of work.

When James had thoughtfully studied all the information he had obtained, he decided to try to become an engineer. He selected the courses that would prepare him for college work in engineering. He joined the clubs in high school that would help him to develop the skills needed to be a suc-

Grand Rapids Public School

The personal problem of how to vote should be handled by the scientific method. Consider the candidates and the positions for which they are running. Gather information about their views, their qualifications, their experience. On the basis of these, reach a decision, and vote accordingly.

cessful engineer. He read the books that would give him additional information about the engineering profession, and made arrangements to work with an engineer friend during his summer vacations. His high-school work was planned. It had purpose. He had used science in solving his problem.

Steps and precautions in problem-solving. It is obvious that James was more successful than Robert in solving his problem. First, he recognized that his main problem was not simply to graduate from high school; it was to determine what his lifework should be. Secondly, he discovered that many other problems or questions had to be answered before he could solve the main problem. He obtained as much information as he could about each question, and then, using that information, he decided to become an engineer. He could now select courses that would prepare him for college work in engineering. Finally, to determine whether or not his decision was right, he worked with an engineer during summer vacations.

The steps in the solution of this problem can be summarized as:

1. Recognizing and understanding the main problem
2. Breaking the main problem down into other problems or questions
3. Gathering information from a number of reliable sources
4. Forming a conclusion or making a decision
5. Checking the conclusion or decision to be sure it is right
6. *Acting on the decision*

These steps are similar to those a scientist takes in solving problems. But you could go through each of these steps in solving your problem and still arrive at an unsound conclusion. To

Brooks from Monkmeyer

In order to get the most for your money when you go shopping, it is important to use reliable sources of information and to recognize those sources that are partial to one point of view.

lessen the possibility of doing this you should observe certain precautions as you solve your problem.

Caution! To be scientific in your problem-solving you must:

1. Be alert to problem situations.
2. Select only the important problems to solve.
3. Understand the problem.
4. Use only reliable sources of information.
5. Use only information dealing directly with your problem.
6. Recognize sources of information that are partial to one point of view.
7. In forming a conclusion or making a decision, use only the information that you have collected.
8. Not take action until you have reached a conclusion or decision based upon definite information.
9. If your information indicates that several solutions might be right, test each before making a final decision.
10. Once you have reached a decision or conclusion to the problem, act.
11. Change your conclusion or decision only when you obtain additional reliable information which shows that your first conclusion was wrong.

SUMMARY

Scientific methods can be used in solving many of our personal problems. In order to use these methods effectively, it is necessary that the problem-solver take certain precautions.

TEST YOURSELF

If the statement is true, write the word *true* in the proper place on your sheet; if the statement is false, write *false* on your answer sheet. **Do not write in this book.**

1. Science cannot be used to help solve the personal problems of boys and girls.
2. Robert failed to understand his problem clearly.
3. Whenever the information you have collected about a problem indicates that several solutions might be correct, flip a coin to decide which one is best.
4. Once you have reached a decision or conclusion to a problem, you should never change it.
5. In solving a problem, you should not use sources of information that are partial.
6. In solving problems, you should use only one source of information so that you will not get confused.

CHAPTER ACTIVITIES

HOW SCIENTIFIC ARE YOU?

Answers to each part of this exercise are to be written on your answer sheet. **Do not write in this book.**

1. Some people believe that a person will have "bad luck" if he breaks a mirror. Which of the following ways would be the best method of testing this belief?

   a. Ask a number of your friends.
   b. Ask a number of adults.
   c. Have each member of the class break a mirror and then keep a record of his "good" and "bad" luck for the week.
   d. Have each member of the class keep a record of his "good" and "bad" luck a week before as well as a week after breaking a mirror.

2. If you were just starting on a trip and saw a black cat cross your path, which of the following things would you do?

   a. Return home and delay the trip another day.
   b. Go ahead but use extreme caution because of the danger of "bad" luck.
   c. Pay no attention to the incident.
   d. Go back to the nearest corner and take a new route.

3. Suppose you were going to buy a new bicycle. Following are a number of smaller problems that you might need to solve in order to help you choose a good one. Which ones are important for you to solve.

   a. How much can I spend?
   b. Where are bicycles manufactured?
   c. What size bicycle would be most suitable for me?
   d. What color bicycle is most popular with my friends?
   e. What kind of bicycle is sturdiest?

UNIT ACTIVITIES

USE SCIENTIFIC METHODS

The exercises at the end of each unit in this book have been prepared primarily to test how well you can use what you have learned in the unit. They also include suggestions for things you can do to increase your understanding of science and to improve your abilities in using scientific methods. Answers to each part of this exercise are to be written on your answer sheet.

1. Which one of the following methods would you use in choosing your lifework? Give your reasons for selecting the method you would follow.

   a. Put off the decision until you have finished high school.
   b. Leave the decision to your friends.
   c. Study your abilities and learn about occupations requiring those abilities before making your decision.

d. Ask someone what you are fitted to do and then follow his advice.

e. Read about various vocations and decide upon the one that sounds most exciting to you.

f. Depend upon your parents to make the decision for you.

2. Which of the following do you consider to be scientific ways of acting? State your reasons for accepting or rejecting each one.

a. Eating a particular type of breakfast food because it was recommended by a famous athlete

b. Brushing the teeth regularly because it was recommended by a dentist

c. Treating a cold with a remedy suggested by a friend

d. Taking certain courses in school because they are said to be easy

e. Buying a particular type of camera because it is most widely advertised

f. Taking pills which are advertised to reduce weight

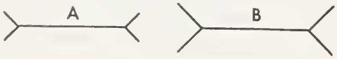
g. Consulting a doctor before taking vitamin tablets

h. Having a thorough physical examination before taking part in strenuous physical activities

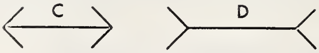
i. Avoiding a party where there are to be only thirteen people

3. As you have learned in this unit, careful and accurate observation is important in scientific work. Are you an accurate observer?

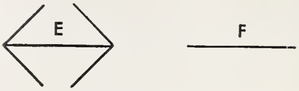
a. Which of the lines below appears to be longer, A or B?



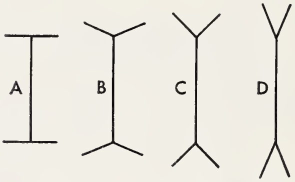
b. Which appears longer, C or D?



c. Which appears longer, E or F?

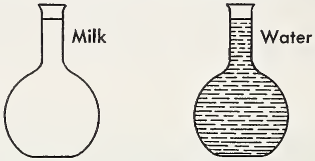


d. Which appears shorter, A, B, C, or D?

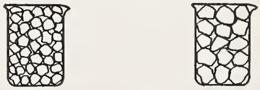


e. How can you check your answers to a, b, c, and d above?

4. Below are two flasks of the same size. One is filled with milk and the other with water. Which one is heavier? How could you check your answer?



5. Observe closely the two beakers below. One is filled with small pieces of coal and the other with larger pieces. In which beaker is there the most air space between the pieces of coal? How could you check your answer?



INCREASE YOUR UNDERSTANDING

1. Collect a number of advertisements from newspapers and magazines in which the term *science* or *scientific*

is used to help sell the product advertised. What meaning of these terms did the advertiser use in each case?

2. Make a scrapbook illustrating the theme "Science in the Modern World."

3. Interview several people, including adults, to determine superstitions they have heard about. Prepare a list of these superstitions and suggest ways in which they could be proved to be false beliefs.

4. Prepare a panel discussion on the subject "The Meaning of Science," and present it in class, at a science-club meeting, or at an assembly program.

READ ABOUT SCIENTISTS

Stories about the way certain scientists have made important discoveries may be found in encyclopedias, books, or magazines located in your school or public library. The following are several references which you may find helpful.

Burlingame, Roger. *March of the Iron Men.* New York: Charles Scribner's Sons, 1938.

A history of inventions in the United States and what they have meant to its development.

Cottler, Joseph, and Jaffe, Hayman. *Heroes of Civilization.* Boston: Little, Brown & Company, 1947.

Interesting stories about the lives and scientific work of some famous explorers, scientists, inventors, and doctors.

Dubos, René J. *Louis Pasteur: Free Lance of Science.* Boston: Little, Brown & Company, 1950.

The life story of Pasteur, showing how he not only made discoveries in his laboratory, but also applied them.

Fermi, Laura. *Atoms in the Family.* Chicago: University of Chicago Press, 1954.

A charming lady tells the story of her life as the wife of Enrico Fermi, one of the greatest scientists of our time. As you will learn later in this book, Fermi built the first atomic pile.

Fielding, William J. *Strange Superstitions and Magical Practices.* Philadelphia: The Blakiston Company, 1945.

A good source book for studying superstitions, past and present.

Floherty, John J. *High, Wide and Deep: Science and Adventure with the Coast and Geodetic Survey.* Philadelphia: J. B. Lippincott Co., 1952.

Recruited mainly from engineering colleges, the men of the Coast and Geodetic Survey must pass rigid tests before entering the service. Their work, ranging from sounding the floor and charting harbors to precision recording of altitude, latitude, and longitude, is both scientific and adventuresome.

Fox, Ruth. *Great Men of Medicine.* New York: Random House, Inc., 1947.

The lives of nine great medical scientists and their discoveries are reviewed in this interesting book.

Garrett, Eileen J., and Lamarque, Abril. *Man: The Maker.* New York: Creative Age Press, Inc., 1946.

A record in pictures of scientific developments that have made it possible for man to control his environment.

Haagensen, C. D., and Wyndham, E. B. Lloyd. *A Hundred Years of Medicine,* New York: Sheridan House, 1943.

This book will help you see what the sanitary and health conditions were in cities a century ago and understand better how far we have advanced.

Hylander, C. J. *American Scientists.* New York: The Macmillan Company, 1935.

This book will help you understand that scientists are human beings like the rest of us.

Hunt, Sir John. *Conquest of Everest.* New York: E. P. Dutton & Company, 1953.

The conquest of the earth's highest mountain involved an enormous amount of scientific planning. This book, by the leader of the successful British expedition, illustrates effectively the application of scientific techniques to problems outside the laboratory.

Poole, Lynn. *Science the Super Sleuth.* New York: Whittlesey House, 1954.

This book tells of the scientific aids to the policeman and detective, such as equipment for identifying small bits of material by suspending them in liquids, the lie detector, the spectrograph, the electron microscope.

Pollack, Philip. *Careers and Opportunities in Science.* New York: E. P. Dutton, Inc., 1954.

The author has assembled information on the science business: the fields of greatest current interest, the study and training needs to get into each, how much you can expect to earn, what scientific careers are open to women, and what leading scientists have to say on scientific education.

Thomas, W. Stephen. *The Amateur Scientist: Science as a Hobby.* New York: W. W. Norton & Company, 1942.

The thousands of amateur scientists in the United States play an important part in scientific advancement. This book will help you understand who they are and how they carry on their scientific work.

Waksman, Selman A. *My Life with the Microbes.* New York: Simon & Schuster, 1954.

An autobiography of Dr. Waksman, from his youth when he saw his sister die of diphtheria to his discovery of streptomycin, for which he received the Nobel Prize.

Bureau of Reclamation

Man's handiwork in taming a river to make it work for him is strikingly shown in this view of Hungry Horse Dam in Montana.

unit 2 ABOVE AND BELOW THE SURFACE OF THE EARTH

BOTH man's opportunities and his very existence depend upon the nature of his home, the planet earth. The earth's atmosphere provides him with oxygen for breathing, protects him from death-dealing radiations of the sun, and, by trapping heat produced by the sun's rays, keeps the temperature of his immediate surroundings within those narrow limits where life can exist. Its water keeps him, as well as all other living things, from dying of thirst, carries much of his commerce, and provides him with a means of recreation. Near the surface of the earth he obtains materials for constructing huge cities, for building machines to improve his living conditions in peace, and to increase his destructive powers in war, and for expressing his sense of beauty through art, music, and personal adornment. It is hardly strange that since earliest times man has been keenly interested in understanding the planet earth upon which he finds himself. Studying this unit will help you broaden your scientific understanding of the planet earth.

You will recall from Unit 1 that it is important when you begin work to understand as clearly as possible what you hope to accomplish. A glance through Unit 2, as well as the rest of the units in the book, shows you that each chapter is divided into problems stated as questions. These question problems center your attention upon what you are going to study. As you progress, you will be given the opportunity to get facts not only by reading but also by observing and experimenting, much as a scientist does. Finally you can judge for yourself how well you are doing by completing activities designed to measure your scientific knowledge, to check your scientific thinking, and to demonstrate your success in using your knowledge and abilities in solving problems.

Bahnsen from Monkmeyer

For all your activities, from playing strenuous games to sitting quietly reading a good book, you need a constant supply of fresh, clean air.

chapter 3 AIR

WITHOUT air man could not exist. Walking, talking, digestion, circulation of blood, and even thinking depend upon the body's obtaining a sufficient supply of air. Moreover, because of its nature, air can be used to run machines to lighten man's labor. His most rapid means of transportation is through the air. Certainly air is one of the most important parts of man's immediate environment. In this chapter you will study air, how man obtains good air for breathing, and how he uses air to do his work.

PROBLEM 1. How do we provide good air for breathing?

THE PHYSICAL NATURE OF AIR

What would happen if you completely filled the bathtub with water and then jumped in? Water all over the floor! This illustrates one of the fundamental ideas of science: Two objects, you and water, cannot occupy the same space at the same time.

If you turn a glass tumbler upside down and push it under water, as shown in diagram A, you will see that water does not fill the tumbler. Why not? The tumbler is apparently empty. Yet it must have something in it or it would completely fill with water. The something is air. This example suggests that even though we can't see air, it occupies space.

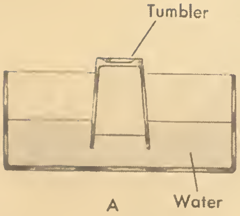
If you balance a bicycle tire when it is fully inflated, as shown in diagram B, and then carefully release the air from the tire, it will no longer be in balance, as in diagram C. Why not? The tire has lost weight. The only difference between B and C is the loss of air from the tire in B. Thus air must have weight.

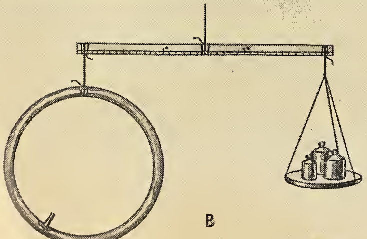
Since air occupies space and has weight, it must be made of a material which occupies space and has weight. Scientists call this material *matter*. All things which occupy space contain matter; the amount of matter they contain determines their weight rather than their size.

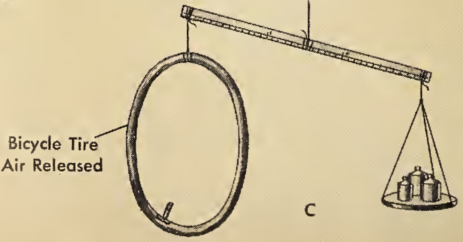
Molecules. Matter is believed to consist of tiny particles called *molecules*. Each molecule in turn is composed of smaller particles called *atoms*. Atoms have weight and occupy space, and therefore the molecules they form also have weight and occupy space. Thus the term *matter* really refers to the atoms and molecules of which a thing is composed.

Molecules are separated from each other by spaces which are small in themselves but large in comparison with the size of the molecules. In some things there is more space between the molecules than in others.

In a *gas,* such as air, the amount of space between the molecules is relatively large. For this reason, there is only a little matter (atoms and mole-





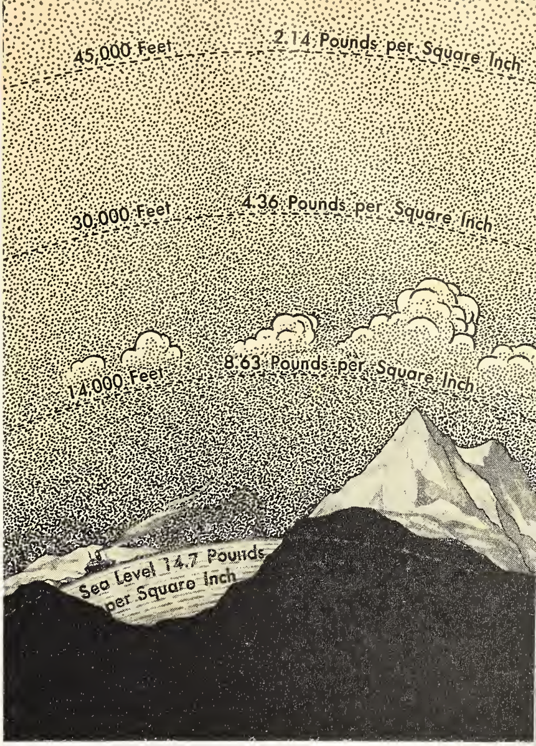


cules) in a gallon of air. In a *liquid,* such as water, the space between the molecules is smaller than in a gas, while in a *solid,* such as a stone, the space between the molecules is even smaller than in a liquid.

Since there are wide spaces between the molecules of a gas as shown on page 30, outside pressure causes the gas molecules to move closer together. The gas then occupies less total space and is said to be *compressed*. Air, being a gas, can be compressed by being pumped into tanks. Liquids and solids, on the other hand, can be compressed only slightly, and with great difficulty.

Movement of molecules. Molecules are always in motion. It is estimated that some air molecules travel at an average speed of about 1,500 feet per second when the temperature is zero degrees on the *Centigrade*[1] thermometer. In each second a single molecule makes about five billion collisions with other molecules. The molecules of a gas travel through greater distances than those of a liquid. The molecules of a solid move relatively little.

Air pressure. Air is all around us. It extends many hundreds of miles outward from the earth. Its total weight has been estimated at 5,000,000,000,000,000 tons. Because of its weight the air pushes against every square inch of the earth's surface at sea level with a force, called *atmospheric pressure,* of about 14.7 pounds. The effect of altitude on atmospheric pressure is shown at right. All objects, including your body, are always being acted upon by atmospheric pressure. Why isn't your body crushed by this tremendous pressure from the outside? Only because there is an equal pressure inside the body pushing out. The two pressures cancel each other, with the result that one does not feel the pressure.


45,000 Feet
2.14 Pounds per Square Inch
30,000 Feet
4.36 Pounds per Square Inch
14,000 Feet
8.63 Pounds per Square Inch
Sea Level 14.7 Pounds per Square Inch

The weight of air molecules (represented by dots) causes atmospheric pressure. A cubic foot of air near sea level contains more molecules than a cubic foot at a high altitude. Thus atmospheric pressure decreases with altitude.

THE CHEMICAL NATURE OF AIR

Some scientists, known as *chemists,* are especially interested in studying the make-up of different things. They have developed a branch of science, *chemistry,* which is concerned with the kinds of molecules and atoms on the earth and how they fit together.

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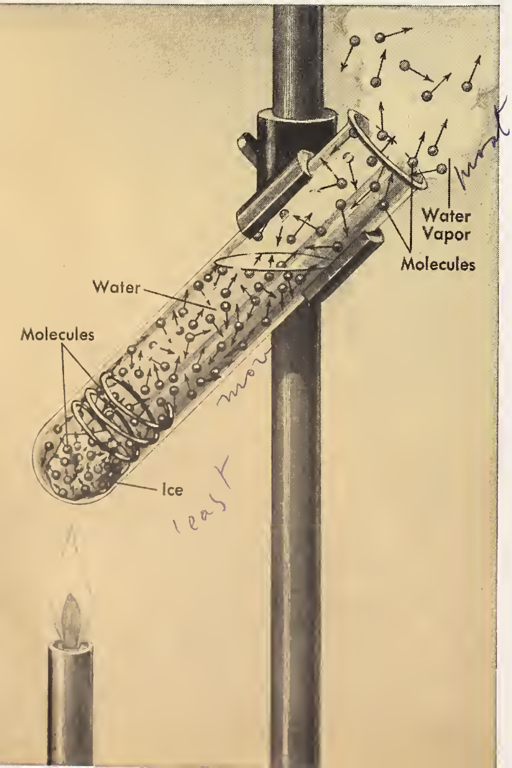
[1] On the centigrade thermometer the freezing temperature of water is zero (0) degrees and the boiling point is 100°. The abbreviation for centigrade is C.

Various combinations of atoms and molecules fit together to form different kinds of matter. These combinations are called *substances*.

Chemically speaking, air is not a single gas, but a mixture of several gases. Just 4 gases make up 99.99 per cent of dry air by volume: *nitrogen* 78.09 per cent, *oxygen* 20.95 per cent, *argon* 0.93 per cent and *carbon dioxide* 0.03 per cent. The remaining 0.01 per cent is made up of *helium, neon, krypton, hydrogen, xenon, radon,* and *ozone*. Air may also contain varying amounts of water vapor, dust, bacteria, carbon particles, and other material added by industrial processes or blown into it from the earth's surface.



In this diagram the length of the arrows indicates the relative motion of the molecules. The molecules move least in ice (solid), more in water (liquid), and most in water vapor (gas).

All of the gases named above except two, carbon dioxide and ozone, are chemical *elements*. There are 93 such elements thought to occur naturally, and scientists have produced 7 additional elements not found naturally on the earth. Some of the more important elements are shown in the table below. You will notice that after each element in the table there is a one or two letter symbol. These symbols are used when referring to one atom of an element.

NAMES AND SYMBOLS OF SOME OF THE MORE IMPORTANT ELEMENTS

Aluminum	Al	Magnesium	Mg
Argon	A	Mercury	Hg
Arsenic	As	Neon	Ne
Barium	Ba	Nickel	Ni
Bismuth	Bi	Nitrogen	N
Bromine	Br	Oxygen	O
Cadmium	Cd	Phosphorus	P
Calcium	Ca	Platinum	Pt
Carbon	C	Radium	Ra
Chlorine	Cl	Silicon	Si
Chromium	Cr	Silver	Ag
Copper	Cu	Sodium	Na
Gold	Au	Sulfur	S
Helium	He	Tin	Sn
Hydrogen	H	Tungsten	W
Iodine	I	Uranium	U
Iron	Fe	Zinc	Zn
Lead	Pb		

Every time you strike a match or make a fire you can do so only because of the chemical activity of one of the elements in the air. That element is oxygen, written by the chemist as O_2. The small 2 is written below and to the right of the symbol to show that whenever oxygen is found as a gas, as in air, it is found as a molecule composed of 2 atoms. This fact, which has been determined by experiments, is also true of some of the other gases in the air, such as nitrogen, N_2, and hydrogen, H_2. Burning is explained by considering the active part of the wood,

Carbon Dioxide and Water Vapor
Carbon Dioxide and Water Vapor
Oxygen
Oxygen
Carbon Dioxide and Water Vapor
Oxygen
Oxygen
Oxygen

Bahnsen from Monkmeyer

Oxygen is used in burning fuel such as the wood in this camp fire, with carbon dioxide and water vapor given off. Our bodies also require oxygen to obtain energy from the food we eat and give off carbon dioxide and water vapor as wastes.

or any other fuel, to be the element carbon, C. When carbon is raised to a high enough temperature, it acts with oxygen, O_2, in the air and *burning* or *combustion* takes place. There are two results from combustion. One is heat, the other a gas called carbon dioxide. Scientists often use Q to represent heat.

Carbon dioxide is not listed in the table of elements because, as you can guess from its name, it is not an element but a combination of two elements: carbon, C, and oxygen, O_2. It is known as a *chemical compound* and is written CO_2. Symbols which represent a compound are known as a chemical *formula*. CO_2 means that two atoms of oxygen are combined with one atom of carbon to form one molecule of carbon dioxide. If you wanted to represent 2 molecules of carbon dioxide, you would write 2 CO_2. Thus a number written to the left of the formula indicates the number of molecules, while one written below and to the right of the symbol of an atom shows the number of atoms of that kind used in making up the molecule. There are literally thousands of chemical compounds on the earth, each made of some combination of two or more of the chemical elements.

Using this chemical shorthand, the process of combustion could be represented as:

fuel + oxygen	acts to produce	carbon dioxide + heat
$C + O_2$	$\longrightarrow$	$CO_2 + Q$

This statement using symbols and formulas is known as a *chemical equation*. By using equations, formulas, and symbols scientists can express a great deal of information in a small space and with a considerable saving of time.

Oxidation. Combustion is one example of *oxidation,* that is, the process of some substance combining with oxygen to form chemical compounds known as *oxides*. Another common example of oxidation is the rusting of iron.

$$\text{iron} + \text{oxygen} \ \overset{\text{acts to}}{\text{produce}} \ \text{iron oxide} + \text{heat}$$

$$4\ Fe + 3\ O_2 \longrightarrow 2\ Fe_2O_3 + Q$$

To a chemist this equation means that 4 atoms of iron act with 3 molecules of oxygen (each molecule of oxygen composed of 2 atoms) to produce 2 molecules of iron oxide (each molecule of iron oxide being composed of 2 atoms of iron and 3 atoms of oxygen) with heat being given off. Do you see why chemical equations are often known as chemical shorthand and are widely used by scientists in their work?

Probably you never thought of rusting as a process which gives off heat. Yet experiments show that it does. But rusting is ordinarily so slow that the heat given off is unnoticed. Rusting is an example of *slow oxidation* while combustion is an example of *rapid oxidation*. But to the chemist they both represent the same type of chemical action, oxidation, which he defines simply as the process of a substance combining with oxygen to produce an oxide and heat.

THE AIR WE BREATHE

Body use of oxygen. Under normal conditions a person breathes about 1400 gallons of air in a day. From this air he uses about 156 gallons of oxygen, O_2. The body uses oxygen principally to release heat from food to help a person carry on his life activities. The heat is released through a process quite similar to slow oxidation but taking place at normal body temperature.

Air pressure and breathing. Since air is a gas, it moves freely from a place where the pressure is high to a place where the pressure is lower. It is because of frequent changes between the pressures inside the lungs and outside the body that we can breathe. The size of our *chest cavity* is increased or decreased by action of the *diaphragm,* a thin sheet of muscles located below the lungs, and the *ribs*. When the diaphragm is lowered and the ribs are raised, the chest cavity increases in size. The air pressure inside the lungs is then lower than the air pressure outside the body, and air therefore moves into the lungs through the nasal passages. This is called *inhaling*. When, on the other hand, the diaphragm is raised and the ribs are lowered, the chest cavity is made smaller. The air pressure in the lungs then becomes higher than that outside the body and the air in the lungs rushes out. This process is called *exhaling*.

Air is changed in breathing. Some of its oxygen is removed in the lungs, and moisture from the lungs and air passages is added to it. Carbon dioxide is also given off by the lungs and exhaled, as shown on page 31.

Contamination of air. Air which contains undesirable substances is said to be *contaminated.* Exhaled air may be contaminated by the body, for when persons sneeze or cough, the air they discharge may contain disease germs of various kinds. Substances having undesirable odors are often added to the air as it is exhaled. Air may also become contaminated by smoke, dust, and poisonous fumes.

Standards for good air. Air should meet four standards to be desirable for breathing. Standard 1, the percentage of O_2 and CO_2 should be about normal. Standard 2, the air should contain sufficient moisture to keep the linings of the air passages from becoming dry and losing their ability to protect the body from harmful germs. Standard 3, air should be between 65° and 70° *Fahrenheit.*[2] Standard 4, the air should be as free as possible from impurities such as dust, soot, disease germs, and plant pollens.

Preventing contamination of outdoor air. About the only way man can improve the quality of outdoor air is by preventing the air from becoming contaminated. In many cities, laws have been passed requiring that smoke-control devices be placed on furnaces burning fuels that give off heavy smoke. Some devices cause the tiny carbon particles called *soot* to settle before smoke leaves the chimney; others cause it to be completely burned. Plants such as ragweed whose pollen contaminates the air should be destroyed before the flowers appear. Contamination of the air with disease germs can be decreased by requiring people to cover sneezes and coughs and by forbidding spitting in public places. Dust can be controlled by spraying unpaved streets and walks with oil or water, and by keeping the fields covered with vegetation or the remains, such as straw, of a previous crop.

Mine Safety Appliance Co.

Testing the air near an industrial city to find out how much it is contaminated. Smoke from the factories in the background can be controlled by means of devices like the electrical precipitator shown on page 34.

AIR CONDITIONING

Controlling the air inside a building so that it will meet the standards for good air is called *air conditioning.* Many devices called air conditioners are not true air conditioners because they do not control the inside air so that it meets all the previously stated standards.

Standard 1. The best way to meet Standard 1 is to replace the inside air with fresh outside air at regular inter-

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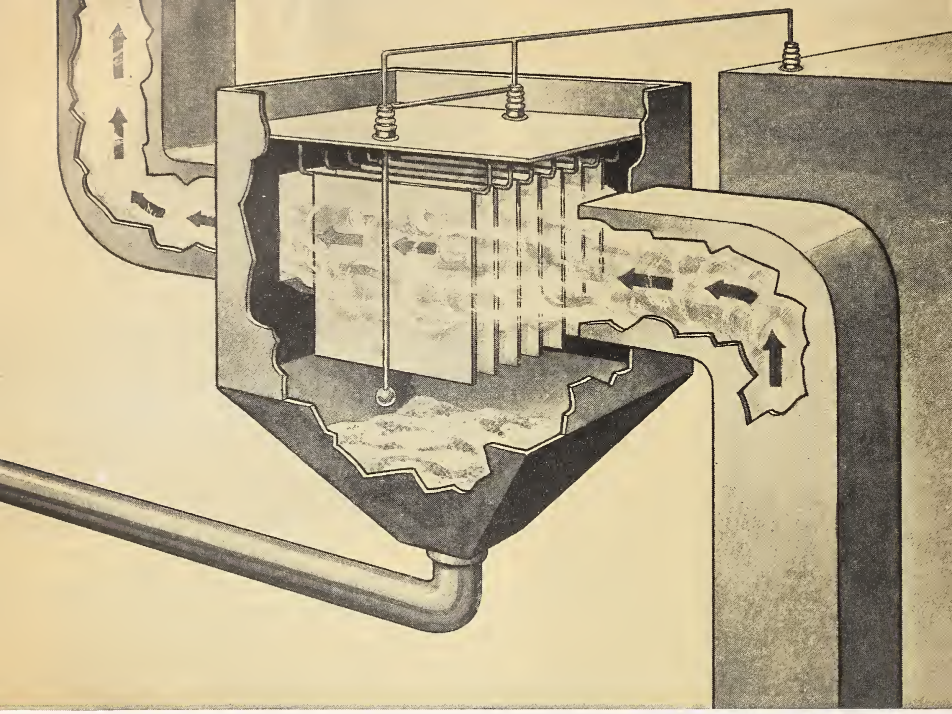
[2] A Fahrenheit thermometer is one upon which the freezing point of water is indicated at 32 degrees (32°) and the boiling point at 212°. The abbreviation for Fahrenheit is F.



Consolidated Edison

This device, called an electrical precipitator, is used to remove soot from smoke. As smoke passes over the electrically charged plates, the tiny particles of soot are deposited on the plates. At regular intervals "rappers" knock the soot into the container below.

vals. The simplest means of obtaining fresh air is through *natural ventilation,* that is, by allowing air to enter directly from the outside. Natural ventilation is most effective when the outdoor air is clean, moist, and of the proper temperature. Windows should be opened from both top and bottom to help air circulate throughout the entire room. Care must be taken, however, to avoid drafts, as they may cool so rapidly that one becomes chilled. When rooms or buildings are air conditioned, outside air is circulated by fans so that the inside air is replaced every few minutes, yet the air movement is slow enough to avoid drafts.

Standards 2 and 3. To be most healthful, the temperature of the air we breathe should be controlled in relation to its moisture content. Most authorities feel that air at temperatures of 65° to 70° F with *relative humidity*[3] of 40 per cent to 50 per cent is best. To meet standards 2 and 3, an air-conditioning system should warm or cool the air, depending on the outside temperature, and should add or extract moisture from the air, depending upon the relative humidity in the building. Almost none of the room air conditioners that fit in windows provide air meeting both of these standards. However, systems which do meet them can be obtained for an entire home.

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[3] Relative humidity is a comparison of the amount of water vapor in the air with the amount the air could hold at that temperature. For a presentation of relative humidity in greater detail, see pages 282-283.

Standard 4. Air can be cleaned by being passed through a spray of water or through a *filter*. A filter is a device which is used to separate one thing from another. Air filters are screens, made of materials such as steel wool, shredded asbestos, felt, or glass fibers treated with oil, that trap and hold the solid particles as the air is forced through them. During one year as much as six pounds of dust has been filtered from the air entering a six-room house. For an air-conditioning system to be most effective, the building must be designed so that all the fresh outside air for the building must be provided and filtered by the system.

Even with the best air-conditioning systems, germs are likely to be present in the air. Studies have revealed that the number of germs carried in the air varies from a few to many hundreds per cubic foot of air in crowded places. Air in some theaters has been found to contain from 10 to 50 germs per cubic foot. The air in a certain crowded cafeteria was tested and found to contain about 88 germs per cubic foot. Since an adult breathes several cubic feet of air every hour, hundreds of germs could be taken into his lungs hourly. Fortunately, they are not all harmful.

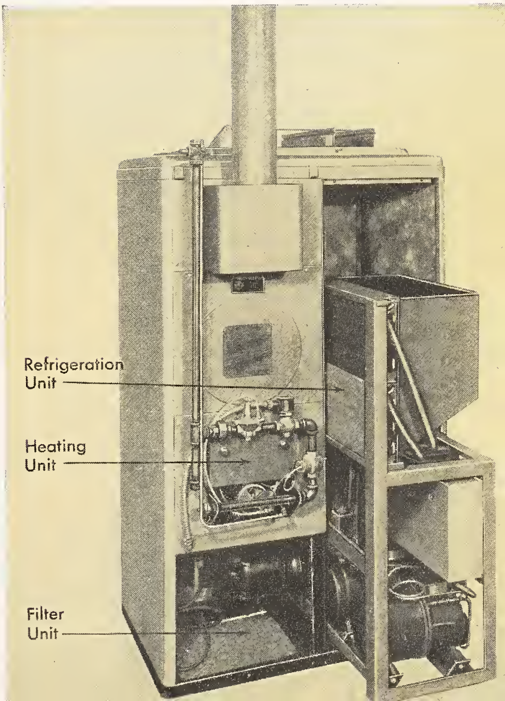
Special lamps which produce a germ killing light are one of the best means yet developed for killing air-borne germs. They can be installed in rooms, in homes or offices, or in the fresh-air intake in air-conditioning systems.

SUMMARY

Air contains matter and has weight and occupies space. Thus, it exerts pressure. Chemically speaking, it contains both elements and compounds. One element, oxygen, is responsible for slow oxidation, such as rusting, and fast oxidation, which we call burning. To be healthful and comfortable, indoor air must contain sufficient oxygen, must be free from undesirable substances, must be between 65° and 70° F, and must be moist. To maintain such conditions, devices which clean, heat, moisten, and move the air have been developed.

A home air conditioner that filters the inside air and keeps it at the desired temperature.

York Corporation



THE EXPERIMENTAL METHOD

Throughout your science textbook you will find experiments that you can perform. Doing these experiments will help you in two ways. First, it will help you to become more skilled in the use of scientific methods, and, second, it will help you to understand scientific information more thoroughly.

The nature of an experiment. An experiment is planned to obtain facts or evidence for a definite purpose. For example, Pasteur used an experiment with sheep to obtain facts to help him solve the problem of protecting sheep from anthrax. The two English scientists, Dr. Florey and Dr. Chain, used experiments to obtain facts to check the accuracy of Dr. Fleming's idea that pure penicillin which would kill bacteria could not be obtained. The experiments you will have in your science course will be planned to either (1) gather facts to help answer a particular problem, or (2) gather facts to test the accuracy of a statement made in the textbook. Thus your experiments are planned to serve the same purposes for you that they serve for scientists.

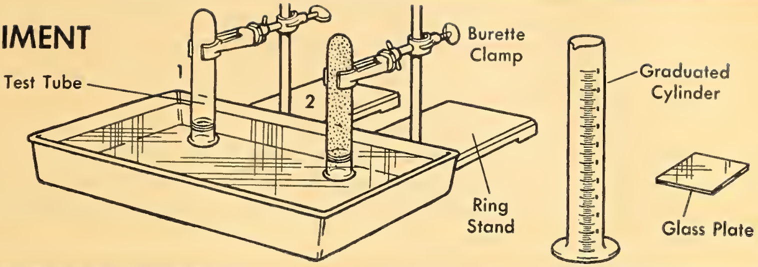
Scientists plan and perform experiments very carefully. After they decide upon a definite purpose for an experiment, they then plan how the experiment can be carried out. The way an experiment is carried out is called the *experimental method.*

Using assumptions in an experiment. In planning the method of performing any experiment, two points must be carefully considered. First, it is necessary to identify and accept certain statements upon which the experiment can be based. These statements are called *assumptions* because they may or may not be true. However, they are accepted as true at the beginning of the experiment and there is no attempt made to prove them during the course of the experiment. The way an experiment is based upon assumptions can be shown best in connection with an experiment that you are going to perform. The use of assumptions, therefore, will be described in the section immediately following the directions for performing this first experiment. You will be using assumptions in the same way in doing all the other experiments in this book.

Importance of a control group. The second point that must be considered in planning an experiment is to be sure that only one cause can be responsible for producing the result obtained. For example, Pasteur had to plan his experiment so that when he had finished he could be sure the injections he gave the sheep were really responsible for keeping them from catching the disease. He used two pens of sheep, keeping the conditions identical in both pens with the exception of the one cause being tested, the injections. The sheep in the pen that were given the injections are known as the *experimental group* while the others are called the *control group*. The only difference between the way in which these two groups were handled was that the experimental group was given injections. Scientists still employ the method used by Pasteur when they are planning an experiment. Your experiments are all planned with controls.

In summary, an experiment is (1) used to gather facts about a problem or to test the accuracy of a statement, (2) based upon certain assumptions, (3) planned to include a control so that a single cause can be said to produce the results obtained.

EXPERIMENT



The statement to be tested. In the textbook on page 30 it was stated that about 21 per cent of the air is oxygen. This experiment is planned to help you gather evidence to test this statement.

What you need. A baking dish or other container; two test tubes with tape bands ½ inch from open ends; a jar of iron filings; 2 ring-stands with burette clamps; a graduated cylinder; and a glass plate.

What to do. Place about 1½ inches of water in the baking dish. Insert the open end of test tube 1 in the water, allowing enough water to enter the test tube to make the water level inside the tube, the water level outside the tube, and the tape all even; clamp the test tube in this position (1 above). Wet the inside of the other test tube, pour some iron filings in it, and shake until the inside of the test tube is coated with filings. Put this test tube in place (2 above) observing the same precautions followed with 1.

Observe the water levels in the test tubes from day to day. After the water no longer rises in the tube containing the iron filings, observe carefully and record the answers to these questions.

1. How do the water levels compare in the two test tubes?
2. What evidence is there that some oxygen has been removed from the air?
3. What evidence do you see that the iron filings have been united with the oxygen?

After you have made your observations, carefully lower the open end of tube 2 into the water until the water levels inside and outside are the same. This will not be at the tape marker. Cover the end of the test tube with the glass plate, taking care to keep the water levels the same. Now lift the test tube out and quickly turn the open end up, making sure that no water falls out of the tube. (**Note:** It might be desirable to practice this step with another tube until you are sure you can do it without spilling water. If any water is spilled from the test tube, the experiment cannot be completed.) Measure the water in this tube with the graduated cylinder and record it. Following the same procedure, remove tube 1 and measure the amount of water it contains. Subtract this amount from the amount of water in tube 2. The difference is equal to the amount of oxygen in the air inside tube 2. In order to find out how much air was inside tube 2, fill it with water to the tape marker and measure the water.

Your answer. Answering these questions should help you come to a conclusion about the statement being tested in this experiment.

1. How does the amount of oxygen in the test tube compare with the amount of air that was in the test tube when the experiment started?

   Divide the amount of water representing the oxygen by the amount of water representing the air in the test tube when the experiment started, multiply by 100, and you should obtain the per cent of oxygen in the sample of air you tested.

2. Does your result tend to prove or disprove the statement being tested?

WHAT TO LOOK FOR IN THE EXPERIMENTAL METHOD

Now that this experiment has been completely described, you need to examine it to see why it was planned as it was. The first thing to look for is the purpose for which the experiment was planned. This experiment was planned to gather evidence to test the statement that the amount of oxygen in the air is about 21 per cent.

Next, what are some of the assumptions upon which the experiment is based? It is known that iron filings will unite with oxygen to form iron rust. Therefore, if iron filings inside a test tube of air are allowed to rust, they should remove the oxygen from the air. Removing the oxygen from the air inside the test tube will decrease the air pressure inside the tube, and water will be forced into the tube. Then by comparing the amount of water which entered the test tube with the amount of water the test tube held when filled to the tape band marker, the per cent of oxygen in the air in the test tube can be determined. Finally, since the air in the test tube is a sample of the atmosphere, it can be assumed that the per cent of oxygen inside the tube is the same as that of the entire atmosphere. Some assumptions upon which this experiment is based can be stated as follows:

1. Iron will remove all the oxygen from the air inside the test tube.
2. The amount of water which entered the test tube is equal to the amount of oxygen removed.
3. The per cent of oxygen in the whole atmosphere is the same as that in the air inside the test tube.

The second test tube is set up just like the first except that it has no iron filings to remove oxygen from the air. The second test tube is the control. Therefore, any change in the first tube that does not occur in the second tube can be said to be a result of the removal of oxygen.

There are several conditions, in addition to the removal of oxygen, which might cause the height of the water in the test tubes to change. Three of these are (1) a change in temperature, (2) evaporation from the surface of the water, and (3) a change in air pressure. You control these conditions by keeping the test tubes close together and placing them in the same container of water, and by adjusting the water level inside and outside each test tube before removing it from the water.

Finally, the methods used in an experiment should be studied carefully to see where errors are most likely to be made. In this experiment it is difficult to remove the test tubes from the water and be sure that the correct amount of water has been left in the test tube. It is also possible that there weren't enough iron filings to remove all the oxygen from the air inside the test tube. When scientists carry out experiments for research they (1) try to reduce all errors as much as possible, and (2) repeat each experiment a number of times so that their final result will be an average of several trials rather than the result of a single trial. They also try to plan several experiments for the same problem so that results from several procedures can be checked against each other. Unless all possible measures are taken to reduce errors one cannot expect highly accurate results.

TEST YOURSELF

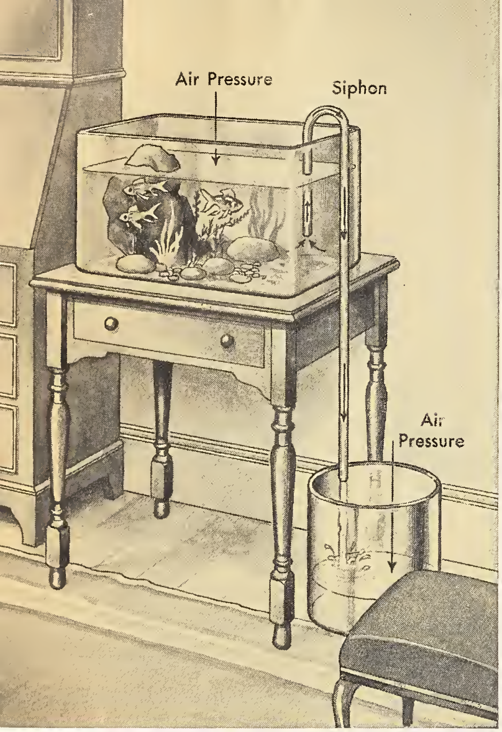
Select the ending which best completes each statement and write its letter in the proper place on your answer sheet.

1. Ordinarily air is (a) a liquid; (b) a gas; (c) a compound; (d) a solid.
2. Anything that has weight and occupies space is known as (a) a solid; (b) a mixture; (c) matter; (d) a compound.
3. The gas found in the greatest amounts in the air is (a) oxygen; (b) nitrogen; (c) hydrogen; (d) carbon dioxide.
4. The chemical formula for carbon dioxide is (a) O_2; (b) Fe_2O_3; (c) CO_2; (d) C.
5. Air moves from one place to another because (a) it wants to move; (b) of equal pressures; (c) of unequal pressures; (d) something blows it.
6. Breathing air is likely to contaminate it by (a) using up the nitrogen in the air; (b) decreasing the water vapor in the air; (c) adding undesirable substances to the air; (d) increasing the oxygen in the air.
7. In conducting an experiment, any statement which is accepted as true without proof is called (a) an hypothesis; (b) a theory; (c) an assumption; (d) a control.

PROBLEM 2. How is air used to do work?

AIR AT WORK

Air develops force. It may be difficult to imagine that something which is invisible like air can be used to do work. To understand this we must first learn what the scientist means when he uses the term *work*. An object does not move unless something either pushes or pulls it. This push or pull is called a *force*. To the scientist, when a force is applied to move an object



When air is removed from the tube forming the siphon, air pressure on the surface of the water in the fish bowl forces water into the tube. Since the weight of the water in the longer tube of the siphon is greater than that in the shorter tube, water flows into the vessel on the floor.

from one place to another place, work is done. Because they have weight, air molecules produce a force which can be used to do work.

Work from atmospheric pressure. Breathing is possible because of the difference in air pressure inside and outside the lungs. Atmospheric pressure depends upon the number and movement of molecules in a given space. The pressure is increased as the number of molecules in a given space increases. It may be decreased by removing molecules from a given space or by increasing the space in which the same number of air molecules is contained. Air moves from a place of high pressure where there are a great many molecules to one of low pressure where there are fewer molecules. The fact that air is composed of molecules which are in motion and which have weight helps explain how differences in atmospheric pressure produce a force which can do work.

The siphon. Sometimes it is necessary to remove water from a vessel such as a fish bowl without tipping the vessel. This can be done by use of a *siphon* (shown at left). Siphons have many purposes. Where water has to be obtained from distant sources, large siphons may conduct it under rivers and over hills. Cream may be removed from bottled milk by the use of siphons. In science laboratories, siphons are used to remove liquids from bottles easily and safely. In siphoning liquids that may be harmful to the body, one should never remove the air from the siphon by sucking.

The lift pump. A lift pump operates because of atmospheric pressure. How it makes use of atmospheric pressure can be learned from a study of the drawings on page 41.

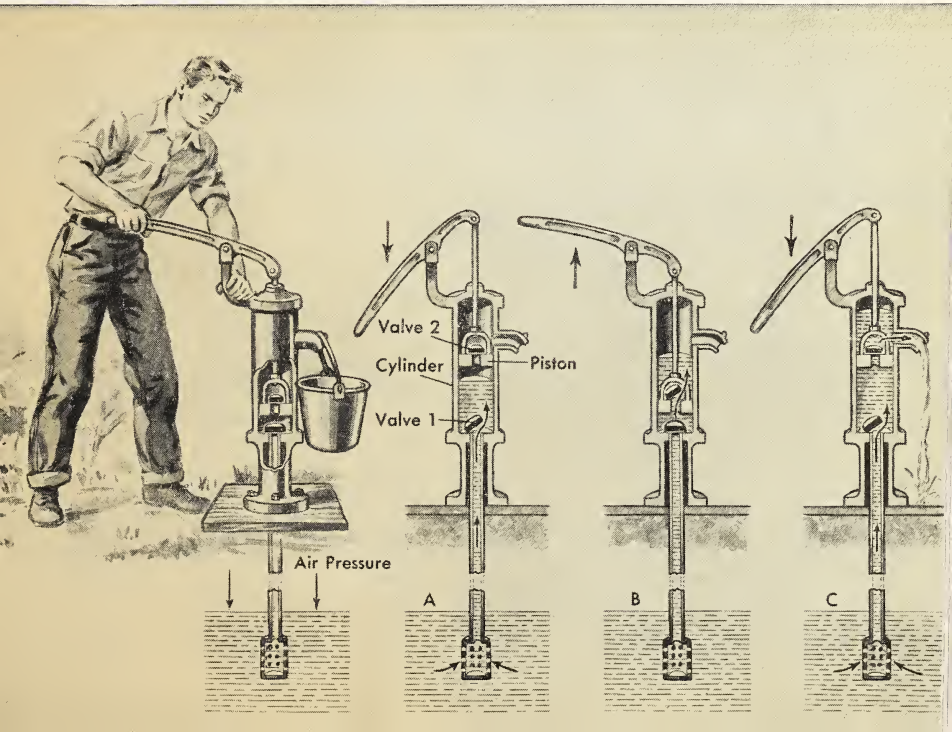
When lift pumps were invented it was thought that they would operate regardless of the distance between the cylinder and the water level in the well. It was found, however, that when the cylinder was more than about 28 feet above the level of the water, the pump failed to operate. It was later discovered that at sea level atmospheric pressure will raise water only about 28 feet in a pipe. If there were no friction between the moving water and the pipe, the atmospheric pressure at sea level would raise the water about 34 feet.

The vacuum cleaner. A vacuum cleaner also depends upon air pressure for its operation. The electric motor drives a fan which pushes air out of the vacuum cleaner. Because the number of molecules of air is reduced, an area of low pressure is created inside the cleaner. Since the air pressure on the outside of the cleaner is now higher than on the inside, air is pushed through the rug into the cleaner. As air passes through the rug, dust is carried with it into the cleaner.

All devices operated by air pressure use some means of reducing the air pressure inside the device. In drinking the soda, sucking on one end of the straw reduces the air pressure in the straw. The falling liquid in the siphon reduces the pressure in one portion of the tube. In the lift pump a piston sliding in a cylinder reduces the pressure, and in the vacuum cleaner a motor-driven fan reduces the pressure inside the cleaner.

Work from air in motion. If you have ever flown a kite, you know that the kite will not fly unless the wind is blowing or the kite is pulled rapidly through the air. A kite is lifted into the air and held there primarily by the force produced when molecules of air hit the kite. Since each molecule of air weighs so little, it is difficult to understand how air molecules can produce enough force to hold the kite up. But when we realize that a thimble filled with air contains about 27 million

The rising piston in A reduces the pressure inside the cylinder and outside air pressure forces water up through valve to fill the cylinder. In B the piston descends with water passing through valve 2. In C the rising piston lifts the water high enough to run out of the spout and also repeats the action at A.



billion molecules, we can understand that the combined force of the moving molecules can be very great.

For centuries men depended almost entirely upon the direct push of moving air to sail their boats. Sails are no longer generally used on large ships, but small boats used for recreational purposes are equipped with sails, and sailing is a popular sport.

The windmills used in some localities to pump water, grind grain, and even to generate electricity are operated by the direct push of moving air.

If you blow across the top of a long, narrow strip of paper, the paper will actually rise. It does not rise as a kite does, because of the force exerted by molecules of air being blown directly against it. The air blown across the top of the paper moves faster than the air beneath the paper. The sidewise pressure of the moving air above the paper is less than that of the air below the paper. Therefore air in the area of higher pressure below the paper moves to the area of lower pressure above the paper and carries the paper with it.

Air is used to do work. Paper cups are blown from the machines where they are formed through glass-like pipes to the packing and shipping areas.

Eastman Chemical Products, Inc.

The idea that pressure is reduced in moving air is known as *Bernoulli's* principle. Bernoulli, a Swiss scientist, first showed that when the rate of flow of a fluid[1] is increased, its sidewise pressure decreases. The reverse is also true. There are many common illustrations of Bernoulli's principle. The curve of a baseball, the cut of a tennis ball, and the slice of a golf ball are caused by the force resulting from a difference in air pressures. This difference is created when the air moves faster around one side of the ball than around the other as it spins.

The *lift* of an airplane—that is, the force which holds the plane up—comes mainly from the difference in pressures between the air above the wing and the air below it. The air above the wing moves faster than the air below it because the wing is constructed in the shape of an *airfoil.* (Drawing on page 43 shows one type of airfoil.) Although the difference in air pressure produces most of the lift of an airplane, some lift is obtained by the force of the air molecules striking the lower surface of the wing.

Compressed air. Almost everyone has blown up a toy balloon. As air is forced inside, the balloon expands. How do the molecules of air furnish enough force to cause the balloon to expand?

To answer this question we must use our knowledge of the structure of matter. We have seen that air molecules are always in motion. Thus bil-

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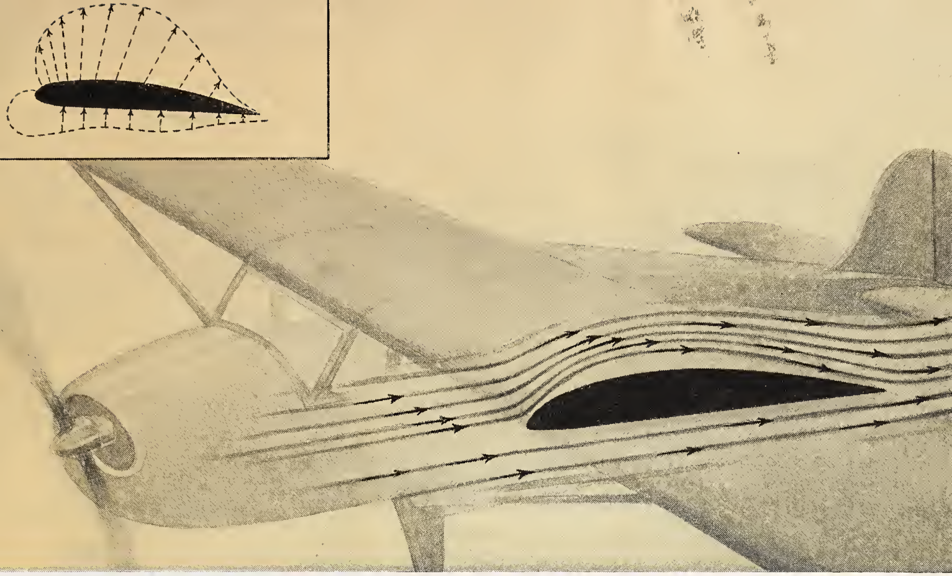
[1] In scientific work, both gases, such as air, and liquids, such as water, are called *fluids*.



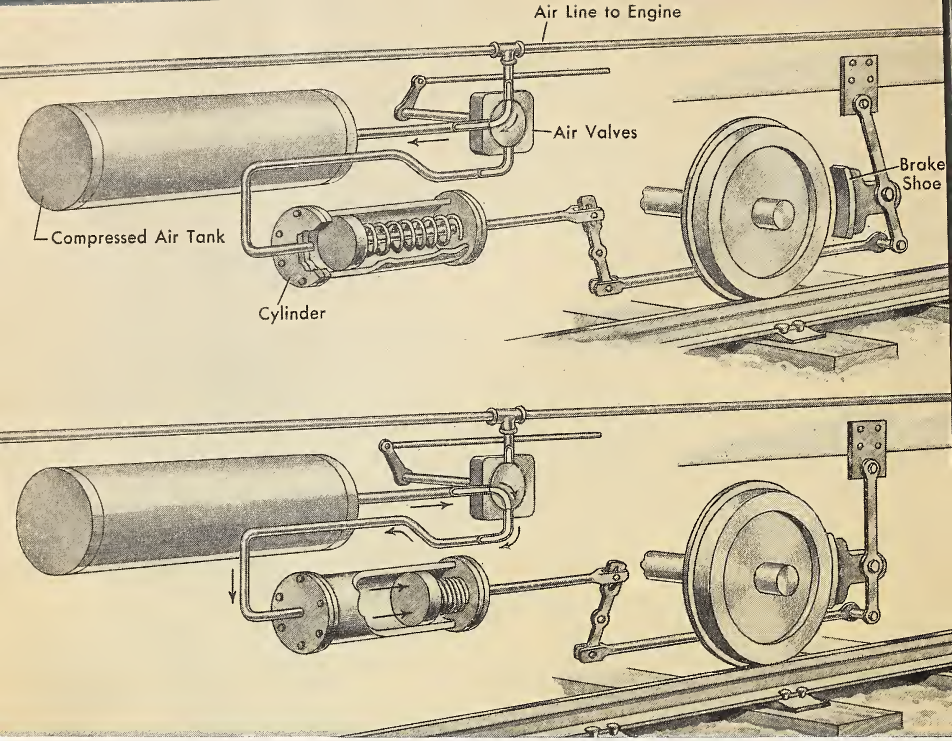
Because of the shape of an airplane wing (airfoil), air moves faster across the top than across the bottom of it. Thus the pressure above the wing is reduced and normal air pressure pushes it upward. The dotted arrows in the inset indicate the relative lift from reduced pressure above the wing and the impact of air against its lower surface.

lions of them are constantly bombarding the walls of the balloon and exerting pressure against them. If the number of molecules inside the balloon were increased, the pressure against the inside of the balloon would be increased because more molecules would be hitting the balloon at every instant. This is exactly what happens when you inflate a balloon. The air molecules you blow into the balloon increase the pressure inside. Since the balloon is rubber, it expands. It will stay expanded as long as the additional air molecules remain inside and bombard the sides of the balloon.

When air is pushed into a container which cannot expand, the air becomes *compressed* inside the container. By pumping, thus *compressing,* air into a steel tank with walls that will not expand, high pressure can be developed inside the tank and can be used to do work by operating machines.

Work from compressed air. Compressed air is used to operate brakes on trains, buses, and many trucks. The air is compressed in metal tanks and piped to cylinders at each brake drum, as shown on page 44. The air brake is one of the most effective brakes for large vehicles.

Air rifles are also operated by compressed air. In some types of air rifles when the trigger is pulled, a spring drives a piston which compresses air at the rear of the bullet. The sudden compression of the air drives the bullet out of the barrel with considerable force. In other types of air rifles, the air is compressed with a small pump attached to the gun. When the compressed air is



A simplified diagram of an air brake on a train. When the brake is off (top), the air in the tank is compressed. The brake shoe is away from the wheel. When the value is turned to apply the brake (bottom), compressed air flows into the cylinder, thus forcing the brake shoe against the wheel.

released, it drives the bullet out of the gun.

Many other devices are operated by the use of compressed air. Air hammers and air drills are valuable tools, some of them operating as rapidly as 20,000 blows per minute. Compressed air is also used to transport containers holding money and written messages through metal tubes to their destination. You may perhaps have seen such carriers in department stores, taking your money to a central office, and bringing back your change.

Some other uses for compressed air. You may have wondered how it is possible for the men building the supports for bridges to work under water. They can do so because they work in a *caisson,* a large, thick-walled, hollow pipe which is lowered into the water. Air is pumped into it until the air pressure is great enough to keep the water out. The caisson, large enough to accommodate several men, makes it possible for them to work under water with safety.

When an automobile or bicycle tire is inflated, the air inside it is compressed. Filled with this compressed air, tires serve as cushions, making bicycles and automobiles ride easily.

SUMMARY

Air, like all matter is made up of molecules which are constantly moving. The distance between the molecules of a substance determines whether it exists as a gas, liquid, or solid. Air usually exists as a gas.

There are four ways to make air work:

1. By using the combined weight of the air molecules known as atmospheric pressure.
2. By compressing air through forcing more molecules into a container.
3. By making air molecules move faster in one place than another, thus causing differences in air pressure.
4. By using the force produced when air molecules drive against an object.

DEMONSTRATIONS

In addition to experiments, your textbook will also include a number of demonstrations that you can perform. Doing these demonstrations as described will help you learn the facts and generalizations of science more thoroughly. What is the difference between a fact and a generalization of science? Such a statement as "air contains the gas nitrogen" is a fact. It is also a fact that air contains the gas oxygen. These two facts, along with fact statements concerning the other gases in the air, can be summed up in one statement: Air is a mixtures of gases. This last statement is called a *generalization,* so called because it is a general statement which summarizes several related facts.

A demonstration compared with an experiment. As you remember, an experiment is used to gather facts to solve a particular problem or to test the accuracy of a statement. A demonstration is planned to help you understand a generalization more thoroughly by showing how that generalization is used in some particular situation. Perhaps you have attended some scientific lecture where the lecturer used equipment to demonstrate some of the things he was talking about in order to make them easier to understand. This was a demonstration.

An experiment is characterized by a carefully planned method which insures that only one cause can be responsible for the result observed. The method is based upon recognized assumptions and is planned so that a con-

The blood contains too much N_2 after men work under high air pressure. Reducing the pressure slowly while resting slows down the escape of the extra N_2 and helps prevent painful cramps known as bends.

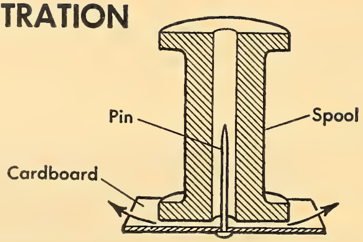
Charles Phelps Cushing

trol can be used. The method used in a demonstration may also be based upon certain assumptions, but there is no control used. Suppose, for example, that you wanted to demonstrate the generalization that a difference in air pressure will cause water to rise in a tube. You could obtain an ordinary drinking straw, place it in water, and suck the air out of the straw. The water would rise in the straw. However, your demonstration would be based upon at least one assumption. The difference in air pressure between the inside and outside of the straw is the only force which causes the water to move up the straw. Only by accepting this assumption can you believe that air pressure rather than some other force pushed the water up the straw. Thus each demonstration may be based upon assumptions.

Finally, in an experiment the evidence observed is used to prove the accuracy of a statement or to help solve a problem, but a demonstration merely shows how a fact or generalization can be used to explain the actions observed. Thus, in the above example of a demonstration, the action of the water moving up the straw was explained by use of the generalization that a difference in air pressure will cause water to rise in a tube.

In summary, a demonstration is used to show a science generalization in action and is based upon recognized assumptions.

DEMONSTRATION



The generalization to be demonstrated. The sidewise pressure in a stream of moving air is less than normal air pressure.

What you need. An ordinary thread spool; a piece of cardboard large enough to cover the end of the spool; and a common pin.

What to do. Blow through the spool at the piece of cardboard, as shown above. Be careful not to blow around the edges of the spool or to touch the cardboard with your hand as you hold the spool. First blow gently, then more vigorously.

What to observe: These questions will direct you in observing the demonstration.

1. When you blow through the spool, is the cardboard blown off?
2. Does the cardboard seem to press more tightly when you blow gently or when you blow vigorously?

What does it mean? In this part of the demonstration use the generalization in explaining the observed action.

1. Since the cardboard did not leave the spool, where was the pressure the greatest?

2. Where is the pressure the least?

A basic assumption underlying this demonstration: The difference between pressure in a stream of moving air and normal air pressure is the only force which causes the cardboard to press against the spool.

TEST YOURSELF

Select the ending which best completes each statement and write its letter in the proper place on your answer sheet.

1. Molecules are always (a) composed of similar atoms; (b) composed of different atoms; (c) in motion; (d) stationary.
2. Increasing the motion of the molecules of a substance may change the substance (a) from a gas to a liquid; (b) from a liquid to a solid; (c) from a solid to a liquid; (d) from a gas to a solid.
3. According to the definition of work used in science, no work is done when (a) an object is raised from the floor to the table; (b) an object is lowered from the table to the floor; (c) an object is pulled along the floor; (d) an object is held steadily in one position.
4. The widest spacing between molecules is found in (a) gases; (b) liquids; (c) matter; (d) solids.
5. A substance such as air that is free to move always moves (a) upward; (b) downward; (c) from a low to a high pressure area; (d) from a high to a low pressure area.
6. A generalization is a statement which (a) summarizes a number of related facts; (b) only scientists can make; (c) everyone understands; (d) does not need to be proved.

CHAPTER ACTIVITIES

REVIEW AIR AND ITS USES

Write the answer to each item in the proper place on your answer sheet.

1. In which form—solid, liquid, or gas—is each of the following substances usually found?

a. nitrogen in air
b. paper
c. oxygen in air
d. wood
e. copper
f. milk

2. Which of the following substances are chemical elements and which are chemical compounds?

a. argon
b. ammonia
c. water vapor
d. oxygen
e. nitrogen
f. carbon dioxide

3. Write the chemical equation for (a) rusting of iron; (b) burning of fuel.

4. On page 48 are 13 devices operated by air. These are followed by four items describing ways in which air produces a force used to do work. On your answer sheet after the number corresponding to each device, write the letter of the item which explains how air

operated the device. Some devices may require more than one item to explain their operation completely.

DEVICES OPERATED BY AIR

1. Vacuum cleaner
2. Lift pump
3. Air drill
4. Air hose for filling automobile tires
5. Fountain pen
6. Windmill
7. Sand blast for cleaning or cutting stone
8. Air rifle
9. Airplane
10. Atomizer
11. Sailboat
12. Air brakes
13. Siphon

WAYS AIR PRODUCES FORCE

a. Atmospheric pressure
b. Compressed air
c. Difference of pressure between stream of moving air and atmospheric pressure
d. Moving air striking something

THINK THROUGH SOME PROBLEMS

1. Some people have a nosebleed when they go to a high altitude. Can you suggest a hypothesis as to the cause of the nosebleed? What facts can you give to support your hypothesis?

2. One afternoon a student attended a theater to see a motion picture that he liked very much. The next day he read in the newspaper that a test made of the air in the theater while he was present showed that the air contained a great many germs. Several days later, the student became ill with a cold. Which of the following statements could be accepted without violating any of the precautions listed on page 20.

a. Since there were germs in the air in the theater, the student caught his cold at the theater.
b. There was no connection between the theater and the cold.
c. The student would not have taken a cold if he had not gone to the theater.
d. It is possible that the student caught cold by attending the theater, but one cannot be sure.

3. Explain the need for "pressurized" cabins in passenger airplanes that fly at extremely high altitudes.

4. How is it possible to use artificial respiration or the iron lung as a substitute for normal breathing?

Philip Gendreau, N.Y.

For centuries man has made falling water work for him. Turned by the weight of the water the wheel operates machinery inside the building.

chapter 4 WATER

IF INTELLIGENT beings viewed the earth from another planet much as we view other planets from the earth, they would be impressed by the fact that the earth alone among the planets is nearly covered with water. If somehow the land areas were leveled until the earth was a smooth ball, the 300 million cubic miles of ocean water would cover the earth to a depth of more than a mile. The seas are the reservoirs from which huge quantities of fresh water are transported over the land to fall as rain. Without rain neither man nor the other living things on the earth could long survive.

PROBLEM 1. How is good water obtained?

THE NATURE OF WATER

The human body is about 65 per cent water. All parts of the body, even bones, contain water. In the various fluids of the body, water serves as a transportation system for food and waste matter. It is essential for the maintenance of life that man have a plentiful supply of good water to use.

Composition of water. If hydrogen, the lightest known gas, is allowed to burn, thus uniting with oxygen, which is also a gas, the resulting oxide is a liquid, water. The chemical equation representing its formation is:

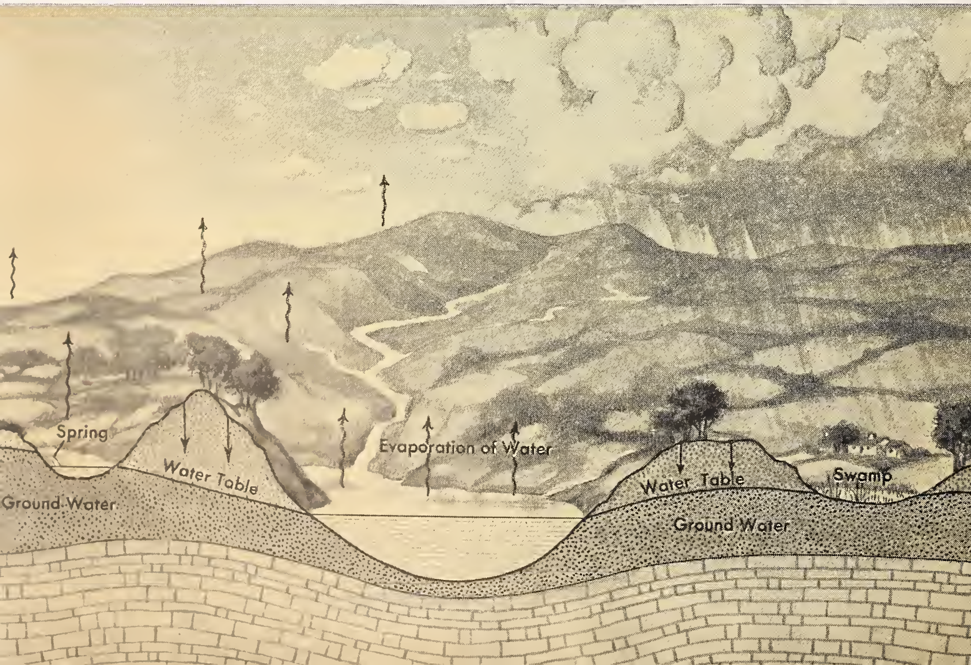
$$2H_2 + O_2 \rightarrow 2H_2O + Q$$

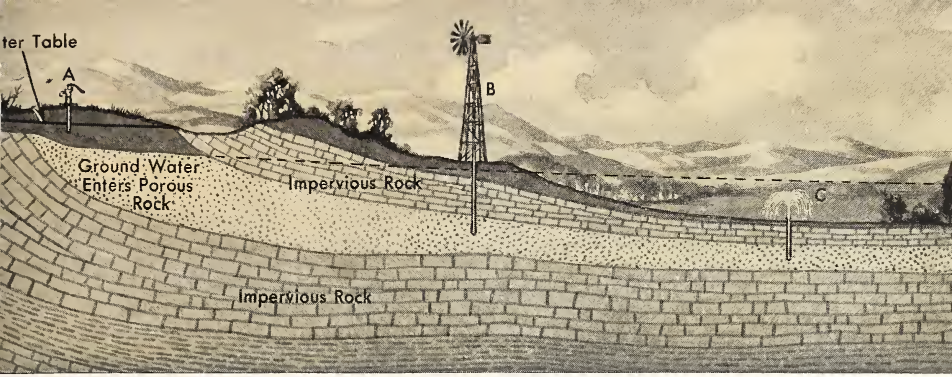
Thus water is a chemical compound, each molecule being composed of two atoms of hydrogen and one atom of oxygen and having the chemical formula of H_2O.

Evaporation and Condensation. Although water molecules are always moving, their average speed depends upon the temperature. As water is cooled, the average speed of molecules decreases until a temperature is reached where the molecules freeze to a solid, ice. On the other hand, as water is heated, the average molecular speed keeps increasing until it becomes so high that the molecules can no longer exist as a liquid but change to a gas, steam.

Fortunately for man, not all water

The water cycle. Water evaporates from the surface of the earth and is later returned as rain or snow. It collects in streams or lakes to form *surface water* or soaks into the earth to form *ground water*, the upper level of which is called the *water table*.





Three types of wells. ***Driven well*** **A is in soil soaked with ground water. B is an** ***artesian*** **well drilled into porous rock containing water, but since the top of the well is above the level (indicated by the broken line) at which ground water enters the porous rock, the water must be pumped out. Water from artesian well C will flow without pumping since the top of the well is below the level at which the water enters the porous rock.**

molecules have the same speed at any given temperature. Some are always moving faster and some slower than the average. Because of this fact, there are always some molecules moving fast enough at any temperature to escape as a gas. These escaped molecules form the *water vapor* that is always present in the air. If this were not so, the air would contain no water vapor until the temperature was high enough to form steam. That is, of course, too high for man to live in. The process of water molecules escaping to form water vapor is called *evaporation*. To remain as water vapor, the water molecules must maintain a speed great enough at any given temperature to keep them from collecting together as liquid water. When they lose speed and return to a liquid they are said to *condense*. The process is called *condensation*.

Evaporation and condensation are extremely important to man. Each year some 24,000 cubic miles of sea water alone evaporates and later condenses over the lands of the earth to fall as rain or snow. This process is known as the water cycle and is shown on page 50. Evaporation is a heat-absorbing process. On hot summer days our bodies perspire, the perspiration evaporates, and our bodies are cooled. Without water to cool the body, man would not be able to survive the hot weather.

Dissolving power. If you place a small amount of sugar in a glass, add some water, and stir vigorously, the sugar soon disappears. If you taste the water you will find it to be sweet. Evidently the sugar disappears by distributing itself throughout the water. The sugar is said to be *dissolved* in the water and the resulting fluid is called a *solution*.

One reason water is important to man is that it will dissolve so many substances. A material which dissolves other substances is called a *solvent*. Water is often called the universal solvent.

Water flowing over and through the earth on its way to the sea dissolves many substances and carries them in solution into the sea. As the water evaporates, the substances are left behind, thus causing the sea water to be "salty." Because of its ability to dissolve so many substances, water in the body is an important carrier of food and other materials to all parts of the body.

Methods of obtaining water. Many cities in the United States depend upon surface water (see page 50) to supply their needs. Some cities, for example New York, Denver, and Los Angeles, have purchased land in the mountains and built dams across the mountain streams to store surface water. Bodies of water stored in this manner are called *reservoirs.* The water from these reservoirs is delivered to the city through large pipes, some of which are 18 feet in diameter. The water is carried as far as three hundred miles to some cities. In other cities, such as St. Louis, Missouri, and Columbus, Ohio, water is taken from nearby rivers, purified, and distributed throughout the city.

Many towns, villages, and most farm homes depend upon ground water for their needs, using wells deep enough to reach below the *water table* (see page 50), and pumping the water to the surface. When the water table is close to the surface of the earth, a shallow well can be used. The water from such a well may be impure, however, because it is often exposed to disease-producing germs. The drawing page 51 shows other types of wells that are used to obtain water from the ground water supply.

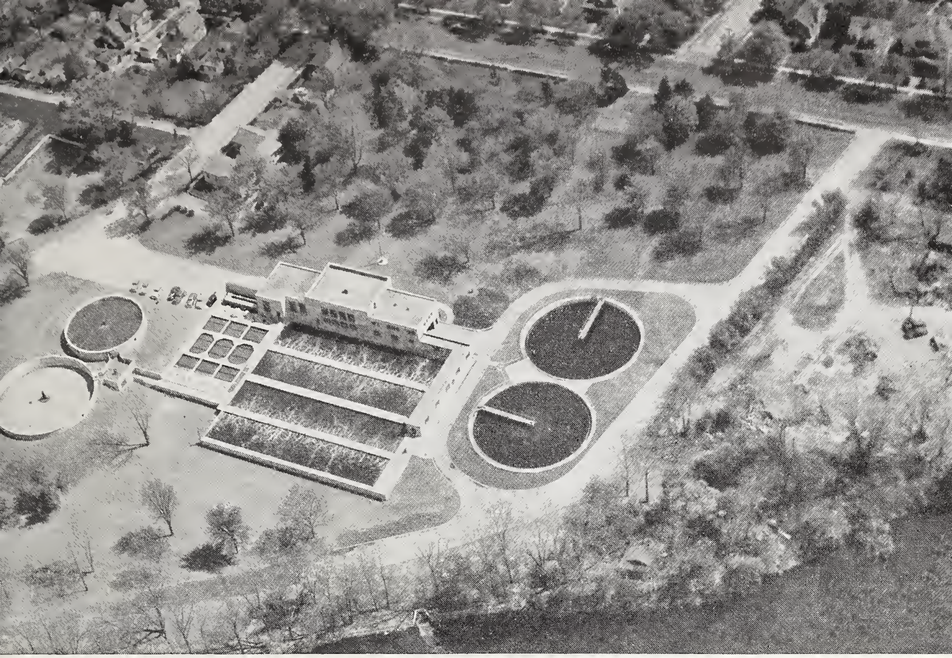
Lakes, springs, and swamps are often caused by ground water coming to the surface (see page 50). If the water table just reaches the surface of the earth, a swamp is formed. If the water table is higher than the floor of a valley, a lake may be formed. If the ground water reaches a sloping surface which is lower than the water table, water will flow to form a spring.

THE WATER SUPPLY SYSTEM

The water we drink should contain no germs that will do our bodies harm. Water contaminated with disease-producing germs is unsafe for drinking purposes. We must therefore prevent animal and human wastes, which may contain harmful germs, from entering the sources of our water supply. Cities using surface water often purchase all the land from which water drains into their reservoirs. This land, known as a *watershed,* is guarded carefully to prevent the water from being contaminated.

Both shallow and driven wells may become contaminated unless they are located so that filth from such places as outdoor toilets and barnyards does not drain into either the well or source of water. The wells must also be constructed so that contaminated water cannot get into them.

Importance of proper sewage disposal. If the water supply is to be safeguarded, proper *sewage* disposal is a necessity. The importance of sewage disposal has not always been recognized. Many communities situated near rivers or streams have allowed untreated sewage to empty into the streams with little thought of its effect on the water supply of other communities. Factories often dump large quantities of waste materials into the streams. As a result, many streams and rivers in this country are *polluted.*

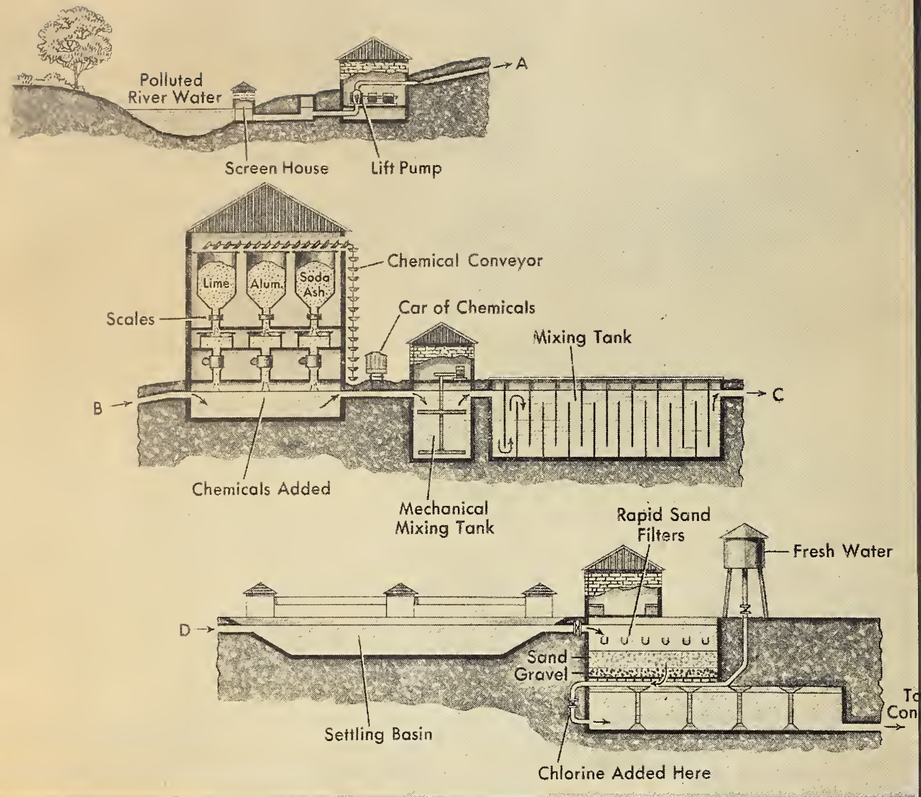


Mishawaka Sewage Treatment Plant

Aerial view of plant. Round digestion tanks with gas holder and floating covers at the left, primary and aeration tanks in the middle, with round final settling tanks at the right. The main building has a garage, offices, and laboratories. It also houses equipment such as pumps, blowers, screens, and grit washers.

A polluted body of water is one into which materials have been dumped that may cause injury to someone. A person or an industry is polluting a river, lake, or stream if, through its use, the water (1) becomes objectionable to any person, (2) will not support fish or wildlife, (3) cannot be normally used by others, or (4) becomes a health hazard. Pollution of a body of water can be avoided by proper sewage treatment.

Modern sewage disposal plants are both attractive and efficient. The sewage disposal plant shown above is a typical example. It is located in a city park near a residential district. Because of the attractive building, beautifully landscaped grounds, and absence of odors, the plant has had little effect upon the desirability of the area for residential purposes. The plant will remove more than 90 per cent of the polluting material in the sewage from a city of 65,000 when operating at full capacity. The sewage can then enter the nearby St. Joseph river without polluting the river water. Another fine sewage disposal plant is located at Phoenix, Arizona. This plant will treat as much as 48,000,000 gallons of sewage per day, the estimated maximum amount of sewage from a city of 200,000. In most plants it is only necessary to remove enough of the polluting materials so that the sewage



A system for making polluted river water safe for consumer use. Water from A enters the section at B where chemicals are added to make the water clear and soft, to destroy germs, and to remove bad tastes and odors. In the settling basin at D, a cotton-like insoluble substance produced by the reaction of chemicals settles to the bottom of the water, which is then filtered through sand and gravel, and finally treated with chlorine.

will not pollute the water into which it flows. In Phoenix the output from the sewage disposal plant is the entire flow of the Salt River below the city. For this reason the plant is designed to give an especially thorough treatment of the sewage. The output from the plant can be made pure enough to pass the bacterial test of the government standard for drinking water. The cost of operating this plant is about ½ a cent per person per day. These examples illustrate the fact that sewage can be treated so that the pollution of streams, lakes, and rivers can be prevented.

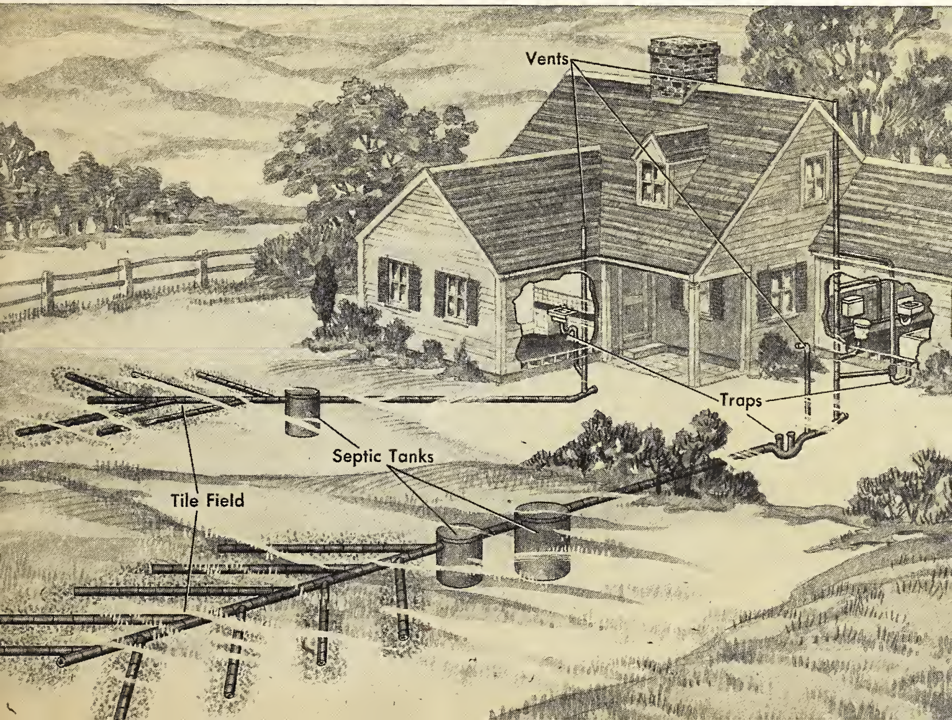
Septic tanks. Where soil conditions are such that it can be installed, a *septic tank* is a good device for disposing of sewage from a rural home with running water when no sewage disposal system is available. Septic tanks should be properly installed and placed where the run-off from them will not drain into the water supply, and they should be cleaned at regular intervals.

Outdoor toilets. Where running water is not available in homes, outdoor toilets are used. Such toilets should have pits lined with concrete so that they can be easily cleaned at regular intervals. They should also be constructed so that flies cannot enter them. The contents of the pit should be sprinkled with chloride of lime every few days to help control odors. Outdoor toilets should be placed at a safe distance from the water supply.

Impurities in water. Water usually contains several kinds of impurities, such as fine particles of mud and sand, dissolved minerals, tiny plants and animals, and sometimes disease germs. Some of these impurities may affect the taste of the water used for drinking, others may make the water undesirable for washing and for certain industrial purposes. Disease germs are the most harmful impurities.

To be satisfactory for drinking, water must meet certain standards based upon clearness, odor, the amount of dissolved chemicals present, and freedom from disease germs. These standards have been established by government scientists. State and local health departments are equipped to test the purity of water. When there is doubt about the purity of a particular water supply, samples may be tested by the local health department. Methods of purifying water are designed either

Septic tanks buried in the ground are constructed so that solid portions of the sewage will settle to the bottom of the tank where they will be decomposed by bacteria. The liquid drains into underground pipes from which it seeps into the soil. Traps filled with water prevent undesirable gases from the tanks from coming back into the house.



(1) to remove the impurities from the water, or (2) to treat the impurities in such a way that they are no longer harmful. In many water-purification systems both methods are used, as shown on page 55.

Distillation. For some kinds of work, especially in scientific laboratories, water must be as free as possible from all kinds of impurities. Such water can be obtained by *distillation,* a process whereby water is boiled and the steam collected and cooled. When water is boiled, the impurities in it are not carried in the steam; they remain in the container. Therefore the steam condenses into pure water. Other methods of removing undesirable chemicals from water will be discussed under the next problem in this chapter.

Treating impurities in water to make them harmless. Some tiny plants and animals, including disease germs, cannot be readily removed from the water. The water must therefore be treated in some way to make these impurities harmless to man. For this purpose, *chlorine* (Cl_2), a chemical element, is generally used. From seven to eight billion gallons of water are treated with it daily in the United States. Tablets containing chlorine have proved useful in purifying small amounts of water when there is doubt about its safety for drinking purposes. Water treated with chlorine frequently has a disagreeable odor or taste from bodies of tiny plants or animals killed by the chlorine.

Odors in water may be removed by *aeration.* In the process of aeration the water is sprayed into the air as a fine mist. The air and sunlight not only help remove odors and tastes from the water, but also kill many of the remaining germs.

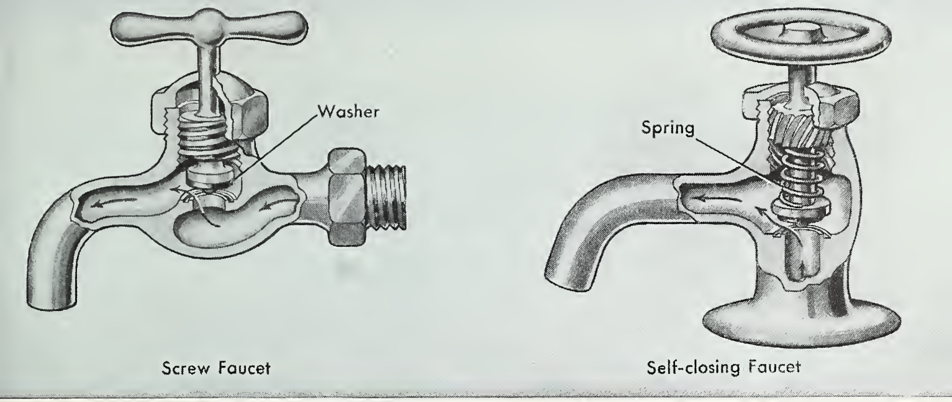
Boiling water for a few minutes will make it safe for drinking. Boiled water has a flat taste because the air has been driven out of it. The taste can be improved by stirring the water so that air again becomes dissolved in it.

Distribution of water. Water is distributed in cities through a system of pipes buried in the ground. It may be forced through pipes by the pressure which results when the source of the water is higher than the places to which the water is being distributed. The pressure at each faucet in the city then depends upon the difference between the height of the storage tank and that of the faucet. The greater this difference, the greater the pressure at the faucet.

When the natural pressure is not sufficient to distribute water satisfactorily, a *centrifugal force pump* is often used. To understand its operation you must know what centrifugal force is. It is the force that tends to make a whirling object fly out from the center about which it is spinning. For example, if you tie a rock to a string and whirl it, the rock tends to fly away from you. The force with which it pulls against the string is the centrifugal force.

To maintain enough water pressure for good service on the upper floors of tall buildings, a centrifugal pump is used in the basement to pump water into a storage tank on top of the building. The storage tank is connected with the water system and helps to equalize the pressure throughout the building. Because centrifugal pumps can move water rapidly and can maintain high pressures, they are used in automobile cooling systems, in fire trucks, on fire boats, and in many other places besides city water systems.

In most cities the water system is



Screw Faucet

Self-closing Faucet

When the handle of the screw faucet is turned the washer is raised, opening the faucet. The faucet is closed when the handle is turned in the opposite direction, thus forcing the washer against the opening to close it. In the self-closing faucet, a strong spring forces the washer to close the opening as soon as the handle is free.

owned by the city and operated by the city government. In some cities each householder pays a fixed amount annually. In other cities water *meters,* which measure the amount of water used, are installed in each home, and charges are based upon the number of cubic feet of water actually used.

In most cities, good water is inexpensive. A constant supply at a low cost is possible because a single water system supplies all the inhabitants. For example, in some cities it is possible to buy as much as a ton of water for as little as three cents.

Individual home water systems. Many rural homes obtain their running water from individual water systems not connected with a city water-distribution system. In these systems, water is pumped from the source of supply into an air-tight tank in or near the house. As it is pumped in, it compresses the air in the tank. When the air reaches a certain pressure, automatic controls stop the pump. The compressed air in the tank then forces the water from the tank into the pipes. After water has been used from the tank and the air pressure is reduced, the automatic controls start the pump.

Homes may also be equipped with individual water systems which operate from a large tank of water on top of a building or high platform. Water is pumped into the tank; from there it flows into pipes supplying the house.

Devices for controlling the flow of water. To control the flow of water into and out of sinks, bowls, and tubs, a screw-type faucet is most often used. See above for an explanation of how it works. Leaking faucets should be repaired immediately to avoid a waste of water. This can be done easily by first shutting off the supply of water to the faucet and then installing a new washer. A slow drip may waste as much as 5000 gallons of water a year.

In public buildings where people are likely to be rather careless about closing faucets, a self-closing faucet like that shown above is often used. These faucets prevent the possible waste of millions of gallons of water annually.

Some public drinking fountains are equipped with a control device called an *electric eye.* As a person bends down to drink, he cuts off the light beam which is striking the electric eye.

When the light beam is cut off, the electric eye operates a device that turns on the water. As soon as the light again strikes the electric eye, the water is shut off.

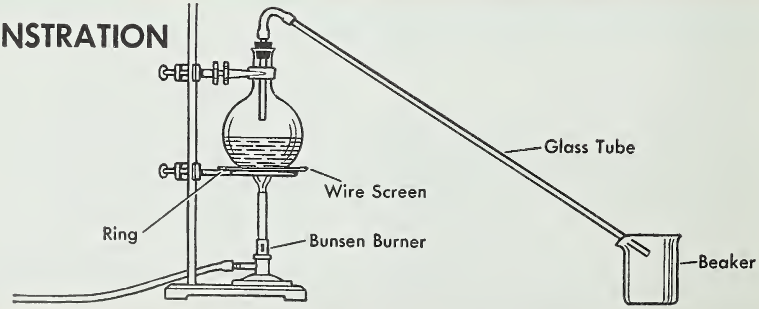
Water used for flushing most toilets is stored in a flush tank. Usually the tank is supported on the wall just above the toilet, but sometimes it is concealed inside the wall. In the tank is a large copper or plastic ball attached to the end of a long metal rod. The ball is hollow and floats. When the outlet valve of the tank is raised and the water is emptied from the tank into the toilet bowl, the water level in the tank sinks rapidly. The copper ball follows the water level. When it drops it opens the valve at the opposite end of the rod, allowing water to enter the tank. After the water from the tank has flushed through the toilet, the outlet valve closes. The incoming water soon fills the tank and the ball, floating on the water, rises. When the ball reaches its top position, it closes the inlet valve, thus preventing more water from entering the tank. The tank is again ready for use. A flush tank should be examined occasionally to be sure that the valves are working properly. Otherwise water may be wasted.

Some flush toilets do not have a tank. Instead the toilet bowl is connected directly to the water pipes. After these toilets are flushed, a valve automatically shuts off the water.

SUMMARY

Water is a chemical compound possessing characteristics which make it essential to all living things. Our supply from both surface and ground water is continually replenished by rain and melting snow. Surface water may be taken directly from rivers and lakes or collected from protected watersheds. Wells are used in order to obtain ground water. Since it is costly to purify and distribute water obtained from its natural sources, it is important that people co-operate in preventing its waste.

DEMONSTRATION



The generalization to be demonstrated. Impurities in water can be removed by distillation.

What you need. A small glass flask; a one-holed stopper to fit the flask; two pieces of glass tubing, one about 6 inches long and one about 18 inches long; a short piece of rubber tubing to fit tightly over glass tubing; a small beaker; some salt; food coloring; water; ringstand with ring; wire screen; burette clamp and Bunsen burner or some other kind of device for heating water in the flask.

What to do. Assemble the apparatus shown above using the equipment listed. Add some salt and food coloring to about ½ beaker of water. Remove the stopper from the flask and pour enough of the colored water in the flask to fill it to a depth of ¼ inch. Discard the remainder of the colored water, place beaker in position, and replace cork and tubing in the flask. Light the burner and boil the water in the flask. Continue boiling until all the water in the flask is gone.

What to observe. 1. Does water form along the entire length of the long tube?

2. What is the color and taste of the water in the beaker?

3. What is the color and taste of the material left in the flask?

What does it mean? In terms of your observations make a statement which tells how salt and food coloring can be removed from water.

Some basic assumptions in this demonstration. 1. Any food coloring present in the water in the beaker can be seen.

2. Any salt in the water in the beaker can be tasted.

3. All impurities would behave as salt and food coloring.

TEST YOURSELF

Select the ending which best completes each statement and write its letter on your answer sheet.

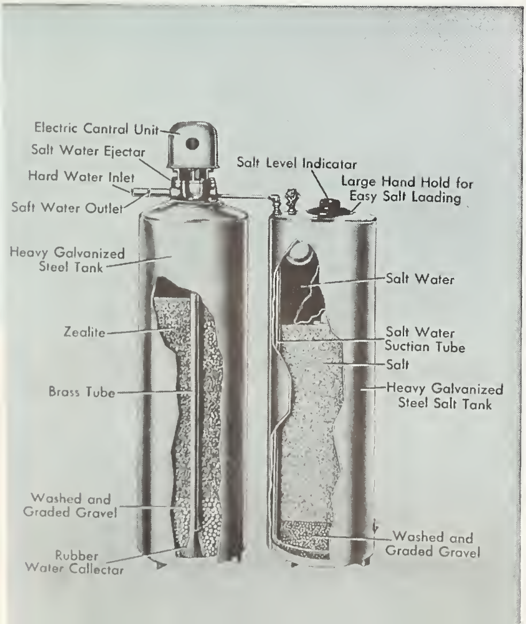
1. Water is least likely to be contaminated if it is obtained from (a) a dug well; (b) a driven well; (c) a drilled well; (d) a river.
2. One of the best methods of disposing of sewage from a rural home is (a) a small activated-sludge plant; (b) a septic tank; (c) an outdoor toilet; (d) to let sewage run into a brook or stream.
3. A substance which is insoluble in water is (a) sand; (b) sugar; (c) salt; (d) chlorine.
4. Although it may not be practical, the surest method of removing all the germs present in water is (a) to aerate it; (b) to filter it; (c) to settle it with chemicals; (d) to distill it.
5. The most widely used method of killing germs in city water supplies is (a) treatment with chlorine; (b) radiation by ultraviolet lamps; (c) aeration; (d) distillation.

PROBLEM 2. How is water used for cleaning?

Water is the most widely used cleaning agent. We use it for bathing, for washing fruits and vegetables before eating or cooking them, for washing dishes, clothes, windows, and cars, and for other purposes. We can do this because water dissolves and washes away many substances that cause our bodies and the things we use to become soiled. Water is inexpensive, and is readily available in most homes. Hot water dissolves substances more quickly than cold water. It is also effective in killing germs on clothing, dishes, and other articles. Steam effectively cleans the outsides of stone and brick buildings, automobile engines, and other machinery by loosening oily or greasy dirt and forcing it off the surface. Steam can also be used effectively to kill germs.

In a zeolite water softener the hard water enters the tank on the left and filters through a mineral called zeolite which removes the chemicals that caused the water to be hard. The soft water is then collected from the bottom of the tank. Salt water from the tank on the right is used periodically to treat the zeolite to prolong its effectiveness in softening the water.

Permutit Company



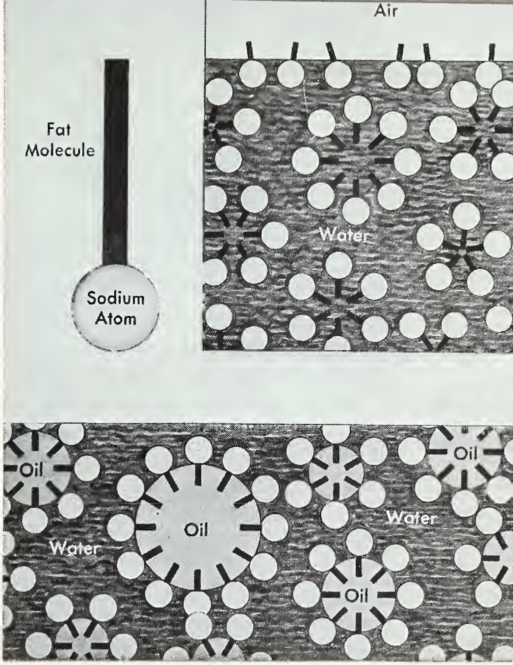
SOAPS IN USE

Soap aids in cleaning. Much of the dirt that gathers on our bodies and our clothes and on the walls, floors, and windows of our homes is mixed with oil or grease of some kind. If you have ever tried to wash greasy dishes with water alone, you already know that even hot water does not dissolve oil or grease satisfactorily. But when you add a little soap to the water, the greasy dirt is easily removed.

Although there are many brands of soap, all are prepared by the same basic process. Soap is made by boiling either animal fat, such as lard or tallow, or vegetable oils, such as coconut or palm oil, with chemical compounds called *alkalis*. *Sodium hydroxide* (NaOH) and *potassium hydroxide* (KOH) are the alkalis used. Sodium hydroxide produces a solid soap known as hard soap. Potassium hydroxide makes a jelly-like soft soap.

Selecting soap. The main purpose of using soap is to aid in cleaning. To remove greasy dirt properly, the soap must form abundant suds. A soap is good if it can produce lasting suds and if it contains a minimum of free alkali. The alkalis used in soap manufacture are harmful to the human skin and to animal fibers, such as silk and wool. Soaps containing a minimum of free alkali, known as *mild* soaps, should be selected for bathing and for washing silks and woolens. More rugged cotton clothing can be safely laundered with a stronger soap.

Toilet soap. Most toilet soaps are carefully manufactured and thus contain little free alkali. They should contain a minimum of water. Their dryness makes them long-lasting if they are handled properly. Immediately after



A soap molecule may be represented in two parts, the sodium being soluble and the fat insoluble in water (top left). Suds are formed when the two parts cluster together (top right). When oily objects are washed, the fat part dissolves in oil, which is surrounded by soap molecules (bottom). The sodium parts dissolve in water, and the oil droplets wash away.

use, toilet soap should be placed in a dish or rack designed to keep it out of water so that it may dry. If in spite of this care the soap dissolves rapidly, it probably means that it contains too much water.

Besides fats and alkalis, a number of other materials can be used in the manufacture of toilet soap. Tiny rough particles of sand or pumice when mixed with the soap increase the cleaning power by helping to loosen dirt. Air whipped into soap makes it light enough to float. Coloring matter and perfume are often added. Air, color, and perfume probably do not add to the cleaning power of the soap, but they may make it more pleasant or convenient to use.

Laundry soap. The yellow color of laundry soaps is often due to the *rosin* substituted for some of the fat in manufacture because it is cheaper than fat. Too much rosin may give the soap a disagreeable odor and may cause white clothes to turn yellowish. Grease-dissolving substances such as *naphtha* in laundry soap are effective when the soap is used in cold or warm water, but in hot water these substances often evaporate so fast that they are of little value. *Borax, washing soda, trisodium phosphate,* and many similar substances are put into laundry soap to aid in producing suds.

Soap chips, flakes and powder. Soap can be purchased in the form of chips and flakes. They dissolve faster than soap in a bar, but they have no better cleaning power. They usually cost more per pound than soap in the bar form. Soap powder, which generally contains the same materials as are used in making bar soap, is powdered by being forced through the openings in a screen. If soap is sprayed from a nozzle and allowed to fall through the air in a tall tower, it forms hollow beads.

Hard water. Have you ever noticed a curdy scum in the water after washing? This means that the water is hard, that is, certain compounds of calcium or magnesium are present in it, which act with the soap to form the curdy scum. Hard water has two main disadvantages. First, the soap used in forming the scum is not available for cleaning; therefore more soap is required to clean with hard water than with soft water. Second, the scum often clings to the object being washed, so that the cleaning is not so thorough. Hard water has other disadvantages. It leaves a hard, scaly deposit on kitchen utensils, such as teakettles, and in hot-water and steam boilers. The deposit reduces the efficiency of the boiler.

Water softening. Hard water may be treated in order to remove the undesirable chemicals by a process called *softening*. As shown on page 55, provisions are made in some city water purification systems to soften the water.

Smaller amounts of water can be softened by filtering the water through a mineral called *zeolite,* which removes the objectionable chemicals. After a while, however, the zeolite loses its effectiveness, but this can be restored by running salt water over it. Zeolite softeners can be obtained in small sizes for use in a single home, or in larger sizes for water-softening plants which serve a community.

For laundry in the home, water can be softened inexpensively by adding a small amount of washing soda or borax.

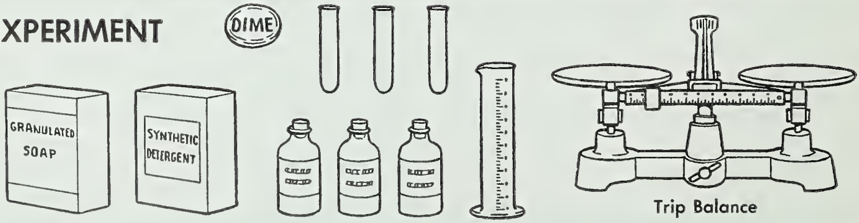
Soapless cleansers. A number of chemical substances have cleaning properties similar to those of soap. These soapless cleaners or *synthetic detergents* may form suds in water; however, their cleaning action is not accounted for by the suds.

Unlike soap, they can be used in hard water without forming a scum. Synthetic detergents are widely used in industry. In the home they are most often used for washing clothes and dishes and as a hair shampoo.

SUMMARY

Water is an important cleaning agent because it is inexpensive and can dissolve many of the substances that cause things to become soiled. It can be used for cleaning in either gas or liquid form. Since oily dirt does not dissolve in water, soap is used to break up the oily dirt into small particles that can be removed with water. A good soap cleans thoroughly without doing any damage. Hard water contains chemicals which make it undesirable for cleaning and for use in boilers. It can be treated with other chemicals to soften it. Soapless cleaners have cleaning qualities similar to those of soap, but they are more effective in hard water.

EXPERIMENT



Problem to be solved. How does a synthetic detergent compare with a granulated soap with respect to (1) producing suds in soft and hard water; (2) the presence of free alkali; (3) causing oil and water to mix; and (4) cost?

What you need. Box of granulated soap and its cost; box of synthetic detergent and its cost; three test tubes; alcohol; *phenolphthalein* solution; light oil or kerosene; graduated cylinder; distilled or soft water; hard water; a dime; a trip balance.

What to do. Part 1. Fill each of three test tubes about three fourths full of distilled or soft water. To one test tube, add the amount of soap which will cover one fourth of a dime; to the second, add the same amount of detergent. (If a trip balance is available, weigh samples for better results.) Add nothing to the third tube. Shake the contents of the three tubes vigorously, keeping the end of the tube closed with the thumb. Compare the amount of suds formed in the tubes.

Repeat the procedure just described, using hard instead of soft water. Compare the amount of suds formed in the tubes. Is there scum present in any tube? If so, which one? Record results.

Part 2. Fill each of three test tubes about one fourth full of alcohol. Add the amount of soap used in part 1 to one tube, and the same amount of detergent to the second tube. Add nothing to the third tube. Add two drops of phenolphthalein solution to each of the three test tubes. In which tube, if any, is there a color change? A change of color to red when the phenolphthalein is added would indicate the presence of free alkali. Record results.

Part 3. Place equal amounts of distilled or soft water in each of the three test tubes. Add 25 drops of oil or kerosene to each of the test tubes. Now add the same amount of soap used in part 1 to one test tube, and the same amount of detergent to the second test tube. Add nothing to the third tube. Shake the contents of each tube vigorously, closing the end of the tube with the thumb. After allowing the tubes to stand for two minutes, observe the amount of unmixed oil that has collected at the top of the water in each tube. Which of the two tubes containing soap or detergent has the smaller amount of unmixed oils? Record results.

Part 4. Find the net weight on each of the boxes of soap and detergent. Change the net weight to ounces. Divide the cost of each by its net weight in ounces. Record the cost per ounce. Which cleaning material costs the most per ounce?

Your answer. 1. How do you know that the soap and synthetic detergent were the only substances which produced the results observed in this experiment?

2. Using only your observations in this experiment, write a generalization to answer each part of the problem.

3. Before you could state a generalization comparing all synthetic detergents with all granulated soaps, what assumption would you have to accept?

4. Based upon the results of this experiment, would you be willing to state which of the materials tested is best for cleaning purposes? State your reasons.

Some basic assumptions in this experiment. 1. The tests used in this experiment are suitable for measuring the ability of a material to produce suds in any water.

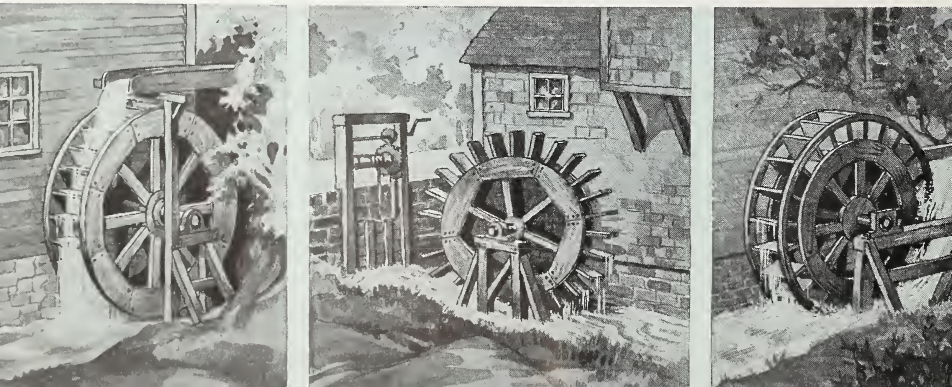
The results observed in this experiment are due entirely to the soap and synthetic detergent used.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words on your answer sheet which should be substituted for the *italicized* word to make the statement true.

1. Water is a widely used cleansing agent because *many* substances will dissolve in it.
2. *Cold* water is an effective germ killer.
3. Soap is made by boiling fat with *perfume*.
4. A soft soap is formed when fat is boiled with *sodium hydroxide*.
5. Soap aids in cleaning by breaking *oily dirt* into tiny particles that can be washed away.
6. When compounds of calcium or magnesium are present in water, the water is known as *soft* water.
7. When undesirable chemicals are removed from a *large* amount of water daily, lime and soda ash are often used.
8. Synthetic detergents will not form a scum in water because they contain no *alkali*.

The three types of water wheels, from left to right, are overshot, undershot, and breast. The weight of water in the buckets is the force turning the overshot wheel. The swift movement of water turns the undershot wheel. The breast wheel is turned by a combination of the forces used in the other two.



THE FIVE HIGHEST DAMS IN THE UNITED STATES

NAME	LOCATION	RIVER	HEIGHT	LENGTH	USES
Hoover	Ariz.-Nev.	Colorado	726	1,244	FC-Irr-P-RR
Shasta	Calif.	Sacramento	602	3,460	FC-Irr-P
Hungry Horse	Montana	South Fork, Flathead	564	2,115	Irr-P-FC
Grand Coulee	Washington	Columbia	550	4,173	Irr-P-RR-FC
Ross	Washington	Skagit	545	1,275	P

FC=Flood Control
Irr=Irrigation
P=Power
RR=River Regulation

From: *World Almanac* 1955
page 212.

PROBLEM 3. How is water used for work and recreation?

FORCE FROM WATER

Since earliest times, man has put water to work. He could use water easily because it naturally flowed downhill to the sea. On its way he could make it turn water wheels, thus developing a force which could do work for him.

Water wheels. Three types of water wheels, the *overshot,* the *undershot,* and the *breast,* were widely used at one time. The way they operate is shown on page 64. These wheels have been largely replaced by the *Pelton* and *turbine* types.

The Pelton water wheel is a metal wheel with cup-shaped buckets built around the rim. The water which turns it is usually collected behind a dam and conducted to the wheel through a pipe. Since the dam is located a considerable distance above the wheel, the water in the pipe is under high pressure. A stream of water flowing at high speed from the pipe is directed against the buckets, thus causing the wheel to turn. Pelton water wheels are made in different sizes and usually turn at high speeds. They are used in small electric-power plants.

The turbine makes the best possible use of the force of running water. It is situated at the lower end of a large pipe called a *penstock,* through which water flows from a dam or natural lake above it. On page 67 you can see how the turbine operates. In Grand Coulee Dam, turbines 50 feet wide and weighing almost one and a half million pounds are supplied with water through penstocks 18 feet in diameter. Water turbines are used to operate *generators* of electric current which is distributed to places where it is used to do productive work. The production and distribution of electricity will be studied in Chapter 10.

Dams. Dams are built across rivers both to store water and to control the flow of water in the river below the dam. The stored water may be used for many purposes. It may operate turbines, supply a city, or be used for growing farm crops. Some of the largest dams in the United States are described in the table above.

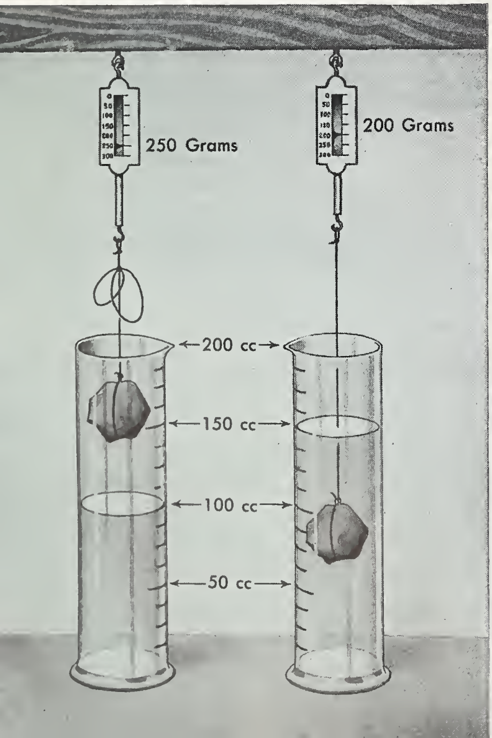
Dams are built thicker at the bottom

than at the top in order to withstand the pressure exerted by the water. The water pressure at the base of the dam depends upon the depth of the water rather than upon the amount of water stored, for water has a pressure of .433 pounds per square inch for each foot of depth.

WATER AND RECREATION

Water for swimming. Swimming is valuable recreation for millions of people in the United States. Each summer beaches and outdoor pools are used to capacity. In some sections of the country where it is too cold for outdoor swimming in the winter months, thousands of indoor pools are used.

When the rock is lowered into the water, the water rises 50 cc. (cubic centimeters), showing that the rock has a volume of 50 cc. and displaced that amount of water. Since 1 cc. of water weighs 1 gram, the rock displaced 50 grams of water. Therefore the water exerts a buoyant force of 50 grams on the rock.



It is great fun to lie on one's back and float in the water. Floating requires little effort. The body seems to be lighter because the water supports it. When you are underneath the surface of the water, the water pushes you upward. This upward force of the water is called a *buoyant* force, or *buoyancy*. It acts against the force of *gravity,* which pulls you downward and gives you weight. If the buoyant force on an object is greater than the pull of gravity, the object will float; if less, the object will sink.

The buoyant force on objects of certain shapes can easily be determined, and it is therefore possible to tell whether they will sink or float. Experiments have shown that the buoyant force of water on any object is equal to the weight of an amount of water having the same volume as that object. You know that volume is found by multiplying length by width by thickness. An object 4 feet long, 2 feet wide, and 1 foot thick has a volume of 8 cubic feet. When placed in water, this object displaces 8 cubic feet of water. The buoyant force is therefore equal to the weight of 8 cubic feet of water. Since fresh water weighs 62.4 pounds per cubic foot, the buoyant force of 8 cubic feet of water is 499 pounds. If the object weighs less than 499 pounds, it will float in water; if it weighs more than 499 pounds, it will sink.

When an object is irregular in shape, the buoyant force which water would exert upon it must be determined by some method other than the one just described. A simple way of finding the

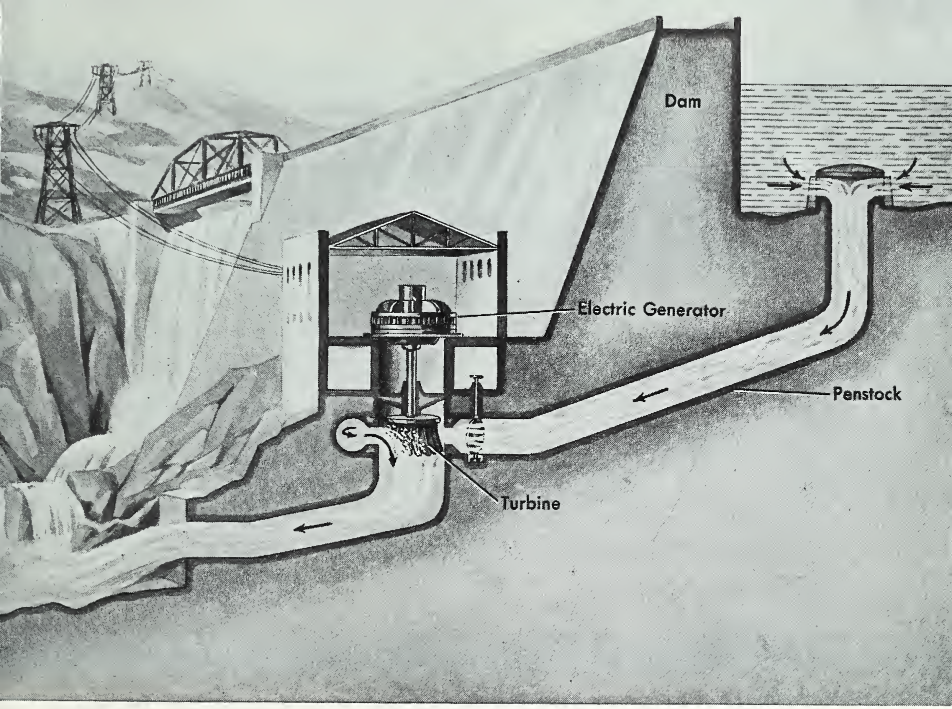


Diagram of a hydroelectric power plant. The turbine is located at the lower end of a large pipe called a penstock. As water flows through the penstock it strikes blades on the turbine causing it to turn. The turbine runs the generator which produces electricity.

buoyant force of water on irregular-shape objects is shown on page 66.

In order to understand these drawings, it is necessary for you to know the *metric* system of measurement. In the metric system the *meter* is the unit for measuring length. It is equal to 39.37 inches. A *centimeter* is $\frac{1}{100}$ (.01) of a meter. Cubic centimeters (cc) are used in measuring volume. *Graduated cylinders* like those in the drawings are used to measure the volume of liquids. *Grams* are used in weighing materials. It takes 453.6 grams to weigh 1 pound. It should be noted here that one cubic centimeter of pure water weighs one gram. The following tables give certain important metric units used in scientific work:

FOR MEASURING LENGTH

1000 m = 1 kilometer (km)
1 m = 1 meter (m)
.01 m = 1 centimeter (cm)
.001 m = 1 millimeter (mm)

FOR MEASURING VOLUME

1 cc = 1 cubic centimeter (cc)
1000 cc = 1 liter (l)

FOR WEIGHING MATERIALS

1 g = 1 gram (g)
.01 g = 1 centigram (cg)
.001 g = 1 milligram (mg)

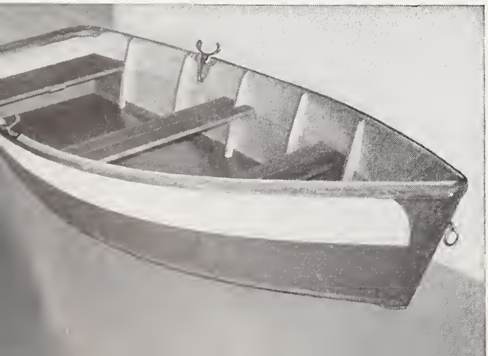
People who are accustomed to swimming in fresh water find it easier to swim in the ocean. This is because the salt in the ocean makes the water heavier than fresh water. A cubic foot of ocean water weighs 64 pounds, whereas a cubic foot of fresh water weighs only 62.4 pounds. Ocean water therefore has a greater buoyant force than fresh water.

Boating. People enjoy getting out on the water in all types of watercraft, from the large, spacious yacht to the simple raft made of a few logs tied together. All watercraft float because of buoyancy. When a boat is put into water, it sinks until the weight of the water which it displaces equals the weight of the boat and its load. Overloading a small boat is dangerous because the boat sinks too deep, thus making it easier for water to enter the boat over the sides.

The various types of watercraft differ considerably in the ease with which they can be upset. Wide, flat-bottomed rowboats are less easily tipped over than narrow, wedge-shaped canoes. Therefore greater care must be exercised in handling canoes than in managing flat-bottomed boats. The load in a boat should be placed on the bottom near the middle. The boat is then less likely to turn over than when the load is higher and located nearer the edges. When the passengers are seated in the center of a rowboat, the boat is not likely to overturn. When passengers stand in a boat, however, their weight is higher and the boat could be turned over more easily. Therefore, when it is necessary to stand in a rowboat, a person should distribute his weight evenly along an imaginary line passing through the middle of the boat.

A flat-bottomed small boat is harder to tip over than a canoe.

Eddie's Boat Shop, N.Y.C.

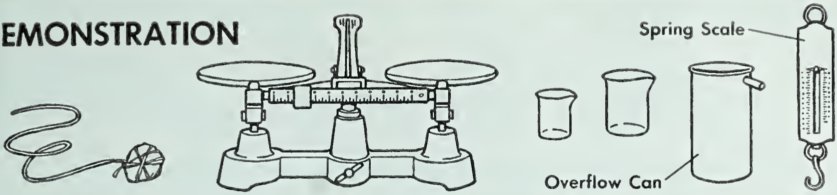


Safety in water recreation. Many people are drowned each year while swimming or boating. The National Safety Council reports that approximately 6700 people drowned in 1953. About half of the people were drowned while swimming or playing in water. Furthermore, the Council's studies show that the number of persons drowned is highest during the vacation months of the summer. Most of those drowned were swimming in places where there were no life guards. The majority of these deaths might have been prevented by the observance of simple safety practices while swimming or boating.

SUMMARY

The weight of water and its tendency to flow to lower levels has made it possible to use water wheels to do work. The turbine is the most efficient type of wheel because it makes the maximum use of the force of running water. Many dams have been constructed to control the run-off of surface water and to provide a continuous supply for the production of electricity. The recreational activities of swimming and boating are possible because of the buoyancy of water.

DEMONSTRATION



Generalization to be demonstrated. The apparent loss of weight of bodies placed in water is equal to the weight of the water they displace.

What you need. A trip balance; a piece of string; a small rock; an overflow can or large beaker; a small beaker; some water; a spring scale.

What to do. Using the spring scale, find the difference between the weight of the rock in and out of water. Make a record of this difference.

Weigh small beaker empty on the trip balance and record its weight. Place the overflow can on a level table and pour in water until it overflows, catching the overflow in the large beaker. When water stops running out of the overflow can, place the small beaker under the spout. Carefully lower the rock into the container filled with water. When no more water runs out of the container, again weigh the small beaker and the water that has run into it. Subtract the weight of the empty beaker from the total weight of the beaker and water.

What to observe. How does the weight of the water displaced by the rock compare with the weight lost by the rock when it was placed in water?

What does it mean? 1. On the basis of your observations in this demonstration, would you be willing to accept the generalization for the above demonstration? State your reasons.

2. What assumptions do you have to accept?

TEST YOURSELF

In the proper place on your answer sheet write the letter of the ending which best completes each statement.

1. If a water wheel is so mounted that paddles along its rim dip into a stream of moving water, the wheel is known as (a) overshot; (b) undershot; (c) breast; (d) Pelton.
2. The most widely used water wheel for obtaining water power is (a) breast; (b) Pelton; (c) water turbine; (d) overshot.
3. If water produces a pressure of .433

pounds per square inch for each foot of depth, the number of pounds of pressure on a square inch at a depth of 20 feet would be (a) 0.866; (b) 8.66; (c) 86.6; (d) 0.216.

4. If an object which weighed 50 pounds and displaced 49 pounds of water were thrown into a lake, the object would (a) float; (b) sink part way to the bottom of the lake; (c) sink to the bottom of the lake only if the lake was very shallow; (d) sink to the bottom of the lake regardless of how deep it was.
5. When water changes to water vapor it is (a) freezing; (b) condensing; (c) evaporating; (d) dissolving.

CHAPTER ACTIVITIES

APPLY YOUR UNDERSTANDING

Two science generalizations studied in this chapter are listed below. Following these are eight questions which can be answered by using one or more of the generalizations. In the proper place on your answer sheet, write the letter or letters of the one or more generalizations which could be used to answer each question. **Do not write in this book.**

GENERALIZATIONS

a. Water pressure at any point depends upon the depth of the water at that point.

b. Any object is held up with a buoyant force equal to the weight of the liquid it displaces.

QUESTIONS

1. Why is a dam thicker at the bottom than at the top?

2. Why are people who have had infantile paralysis often exercised in tanks of water?

3. Why is there a limit to the depth a diver can go?

4. Why do boats sink deeper in the water as they are loaded?

5. Why does water in a gravity water system sometimes flow faster from a faucet in the basement than from one on the third floor of a building?

6. Why are water-supply reservoirs often located at a point higher than any of the buildings receiving water?

7. Why is it easier to swim in salt water than in fresh water?

8. Why will a stick with a weight tied on one end sink deeper in alcohol than in water?

USE THE SCIENTIFIC METHOD

Write your answers to each of the following in the proper place on your answer sheet.

1. Surface water is generally softer than water from a deep well. Suggest a hypothesis to explain why you believe this statement to be true.

2. One of the generalizations studied in this chapter was "Water pressure at any point depends upon the depth of the water at that point." Plan a method for demonstrating this generalization using only a tall tin can, hammer, nail, and some water. Perform the demonstration for your class.

U.S. Geological Survey

Through countless ages the wind, carrying small particles of sand, is thought to have worn away these exposed rocks in the Red Buttes of Wyoming.

chapter 5 THE SURFACE OF THE EARTH

WE have seen that the air surrounding the earth and the water on its surface are necessary for life. The rocks and the soil that make up the land surface of the earth are also important to us. It is among the rocks and on the soil that we make our homes. All our food, with the exception of sea foods, comes from the soil. We should therefore understand what soil is, how it was formed, and what changes take place in it. The earth also is a storehouse of such materials as building stone, coal, oil, metals, sulfur, and salt, which are daily necessities in our present civilization. The supply of these materials in the earth is limited. If we understand how many hundreds of years it took for these materials to be formed and how rapidly they can be destroyed by unwise use, we shall see how important it is to use them carefully, not wastefully.

PROBLEM 1. What changes are occurring in the surface of the earth?

SOLVING PROBLEMS

The indirect method. Both in private life and in scientific research, problems are found which cannot be solved through the use of direct observation or controlled experimentation. In such cases, the indirect approach can often be employed effectively.

For example, suppose you came upon a stalled truck, with warning flares still out, that had been hit by a car. You wonder why the driver of the car couldn't have avoided the accident by putting on his brakes. Observing long tire skid marks leading to the wheels of the wrecked car, you decide the driver of the car did apply his brakes and, as a result, the tires slid. You did not *see* the brakes applied or the tires slide. You simply reasoned that *if* the tires made marks upon the pavement, *then* they must have been sliding; that *if* they slid, *then* the brakes must have been applied. You may further reason that *if* the skid marks are long, as they are, *then* the car must have been traveling fast. You conclude that the driver could not avoid hitting the truck because he was driving too fast. Because it involves *if* statements with *then* conclusions based upon them, this method of indirect reasoning may be called the *if—then* method.

Although the *if—then,* or indirect, method of solving problems is valuable, a number of precautions must be taken in using it. First, the original observations must be as accurate as possible. Second, the observations must be related to the problem. If, for example, the skid marks observed in the accident had been made by another car at another time, it would have been wrong to conclude that the driver in this accident applied his brakes. Finally, it should be remembered that conclusions reached by the indirect method cannot always be accepted as final conclusions. Additional study and observation may uncover facts which make it necessary to change the first conclusion and lead to a different one.

How old is the earth? As they have not discovered any way of measuring the earth's age directly, scientists use the *if—then* method in attempting to answer this question. One clue to the earth's age is the saltiness of the oceans. Assuming that the saltiness of ocean water is caused by salt brought in by rivers, it is reasonable to believe that by dividing the total amount of salt in the oceans (estimated to be 40,000,000,000,000,000 tons) by the amount carried by rivers to the ocean each year (estimated to be 400,000,000 tons) the approximate age of the earth (100,000,000 years) may be determined. The accuracy of this conclusion depends upon the accuracy of at least three *if* statements:

if the ocean has been accumulating salt since the beginning of the earth,
if this accumulation has taken place at the constant rate of 400,000,000 tons per year,
if all the salt in the ocean has been accumulated in this manner,
then the earth is at least 100,000,000 years old.

Scientists do not accept this estimate of the earth's age because the *if* statements involved are open to question.

Throughout much of the earth's history, the continents were probably quite flat. Less land was exposed than is today. As a result, the rivers may have carried as little as one tenth the salt they do today. Taking this into consideration, it is estimated that the oceans are about one and a half billion years old. But even if the exact age of the oceans were known, it would not follow that the earth's age is the same. It is probable that for a long time the earth was so hot that water could exist only as steam. Only after years of cooling could the oceans have begun to form.

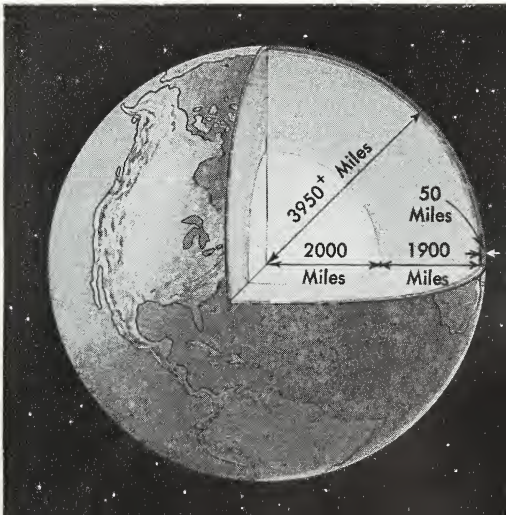
Another *if—then* estimate depends upon the behavior of radioactive elements.[1] *Uranium* and *thorium* are two such elements found in rocks. Both of these elements pass through a series of stages and finally become *lead*. The time required for this process is known and seems to be independent of outside factors. Thus:

if a rock is as old as the earth,
if the rock originally contained no lead like that coming from the break up of uranium,
then the earth is as old as the time required to form the lead it now contains from uranium.

Scientists have estimated the age of rocks from many parts of the world by measuring the amounts of uranium and lead in them. The oldest rocks so far studied are about 2 billion years old. Thus it is believed that the earth is at least 2 billion years old.

The solid earth. Strangely enough, although man lives on the surface of the earth, he knows very little about its interior. Except for the very thin outer surface which can be studied directly, all his information must be obtained by the *if—then* method. *Geologists,* scientists especially interested in studying the earth, undoubtedly know more about the earth's structure than did ancient man, yet the geologists themselves would be the first to admit that their present ideas need revision.

In the world's deepest gold mine in South Africa, a half-million dollar air-conditioning system had to be installed to keep the miners from being roasted. At the bottom of the world's deepest oil well, the temperature is almost twice as hot as boiling water. Scientists have calculated that for every 60 feet of depth in a mine or well, the temperature increases about 1° F. If this rate of temperature increase continued, the melting point of rocks, about 2200° F should be reached at



A section cut from the earth would reveal a crust 30 to 50 miles thick. At the center is a core of heavy melted material. It is probably iron and nickel at a temperature of several thousand degrees and under a pressure of 23,000 tons per square inch. Between crust and core is a layer of melted, heavy rock.

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[1] A radioactive element breaks up by continually shooting off its parts and releasing energy until it finally becomes a different element that is no longer radioactive.

U.S. Geological Survey

Tiny trees sometimes begin growing in small cracks in a rock. As they grow, their roots exert enough force to split the rock apart, thus aiding in weathering.

about 30 miles. Many measurements of lava in volcanoes indicate that this estimate is fairly accurate.

The earth's solid crust, from 30 to 50 miles thick, is thought to be largely composed of two types of rock, *basalt,* a heavy, black rock often found in lava from volcanoes, and *granite,* a lighter, more commonly known rock. The continents are almost all granite. The ocean beds are mostly basalt. Both are considered to be floating on melted rock which extends from the bottom of the solid crust to the earth's core. In all probability the earth is not solid at all, but is only a solid crust floating on a hot, heavy material which behaves somewhat like putty. Page 73 shows the probable structure of the earth.

The earth's crust. It is thought that at one time the earth was a ball of hot, melted rock. As it slowly cooled, a solid crust began forming. Further cooling increased the crust's thickness but also caused the earth to shrink in size. Thus the outer crust folded and wrinkled much as the skin does on fruit as it dries. This action formed the original mountains and valleys of the earth. From that time the earth's crust (scientists call it the *lithosphere*) has been undergoing constant change.

According to their origin the rocks in the lithosphere are of three different types: *igneous, sedimentary,* and *metamorphic.* Igneous rocks, such as granite, were formed when melted material from deep in the earth came to the surface and hardened.

As soon as igneous rocks form, they begin slowly to break, crumble, and dissolve. The process by which rocks are broken down is known as *weathering.* One of the most powerful forces of weathering is the alternate freezing and thawing of water. Water seeps into the joints and pores of a rock, and then freezes. When it freezes, the water expands as much as $\frac{1}{11}$ of its size. At the freezing point, the expansion force is about 2,000 pounds per square inch, but at 8° below zero F this force has increased to 34,000 pounds per square inch. This tremendous force expands the rock slightly. The ice melts, then freezes again, spreading the rock a little more. Finally the rock breaks.

Weathering also results from a variety of chemical actions. Water dissolves some substances, such as CO_2 and material from decaying plants and animals, forming a solution which acts on the rocks. Some rocks contain substances which combine with O_2 to form oxides; these in turn unite with water to form a chemical compound that expands and breaks the rock into tiny bits. This latter action has turned granite near Washington, D. C., and in the Sierra Nevada mountains into rock so soft it can be dug with a spade. Weathering is important to man because it is the means by which *soil* is formed. The significance of soil, its formation, and its conservation will be considered in Unit Ten.

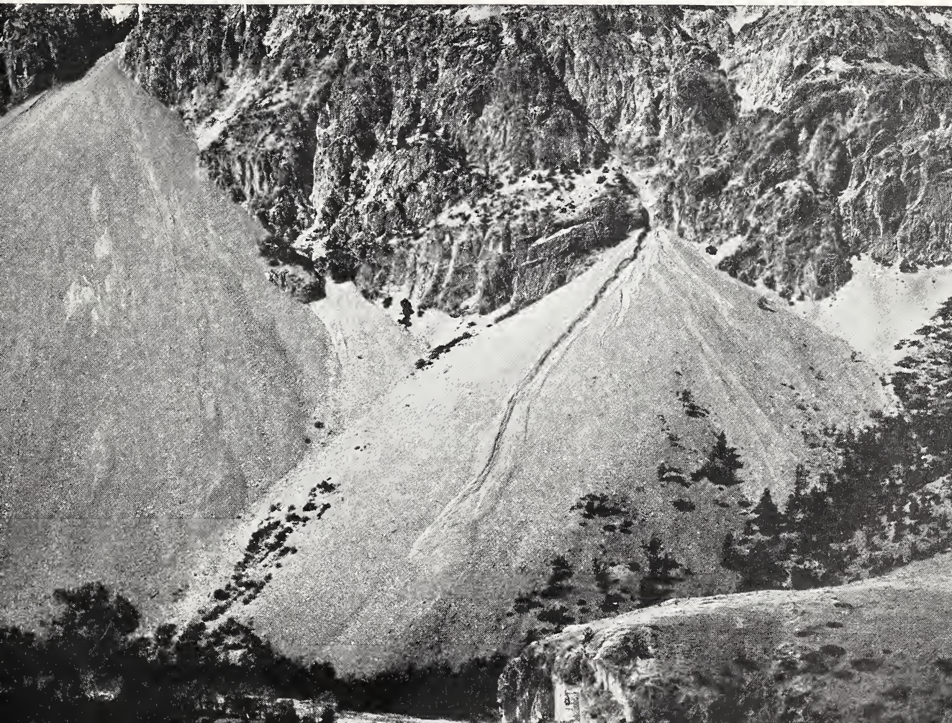
The bits and fragments of rock resulting from weathering are then moved away by the combined action of wind, water, and gravity. Eventually these fragments, as well as some dissolved chemicals, are dropped by the carrying agent to form large beds of *sediment*. By a process not too well understood, the particles may become cemented together, harden, and form one type of *sedimentary* rock. *Sandstone, shale,* and *limestone* are common sedimentary rocks of this type. Another type of sedimentary rock, coal, will be decribed in Problem 2 on pages 83-85.

Rocks are sometimes acted upon, usually by heat and pressure, in a manner which changes their original character. Such changed rocks are called *metamorphic* rocks.

To determine the amounts of chemical elements in the lithosphere, scientists have studied thousands of rock samples taken from deep wells, mines, and places where rocks, once buried,

A great pile of rock, known as a talus cone, is often built up at the base of a mountain. The rock is broken from the face of the mountain by alternate freezing and thawing, and is moved down by gravity and running water.

U.S. Geological Survey



have been pushed to the surface. Estimates of the percentages of the chemical elements making up the outer 10 mile layer of the lithosphere are shown in the table below.

ELEMENTS IN ORDER OF THEIR ABUNDANCE IN THE TEN MILE CRUST IN LITHOSPHERE

(Based upon studies of Clarke and Washington)

ELEMENT	PER CENT
1. Oxygen	46.71
2. Silicon	27.69
3. Aluminum	8.07
4. Iron	5.05
5. Calcium	3.65
6. Sodium	2.75
7. Potassium	2.58
8. Magnesium	2.08
9. All others	1.48

Most of the elements in the lithosphere are found not as pure elements, but in combination with other elements as chemical compounds. Among the few found as elements are copper, gold, silver, and sulfur. Some of the more important compounds, together with their chemical formulas, usual appearance, and uses are shown in the table facing. A substance found in the lithosphere which has a uniform chemical composition and was never a living thing is known as a *mineral*. Thus the elements and compounds listed above and in the table are minerals.

LEVELING THE EARTH'S SURFACE

People who hike in mountains often find the remains of sea animals in rocks high up on mountainsides. How could they get there? The mountains were once covered by the sea. It may seem incredible to you to think that high mountains were once beneath the sea. In your lifetime you will see little if any change in the features of the earth. However, you must remember that a lifetime of 70 years is extremely short considering the fact that the earth has probably been in existence more than 20 million lifetimes. Continuous gradual change occurring through thousands, even millions of lifetimes, produce enormous changes in the features of the earth.

Erosion. After a hard shower you can see tiny streams flowing downhill over sloping ground. Closer examination will show that they are carrying sand, gravel, and other small bits of material. Suppose these streams were thousands of times larger. They would then be raging flood waters capable of moving gigantic stones weighing many tons. Moving water is one of the most active forces of *erosion*. Erosion is the transporting of material which results from weathering (see page 74). It is estimated that the Mississippi River alone carries about half a billion tons of material into the Gulf of Mexico each year. Moving sea water resulting from continuous action of the tide and surf and occasional violent storms, breaks down cliff walls, grinds the rock finer and finer and eventually moves it seaward.

Mass wasting. The soil on a slope slowly moves downhill under the continuous pull of gravity. This slow movement is known as *creep*. On one slope along which a railway was built, the soil moved from 6 to 10 feet in 50 years, forcing frequent repair of the railbed. Sometimes large masses of earth slide suddenly down a slope, thus forming a *landslide*. In 1903, at Frank, Alberta, Canada, some 40,000,000 cubic yards of rock broke away

SOME COMMON MINERALS

NAME	FORMULA	APPEARANCE	USES
1. Bauxite	$Al_2O_3 \cdot H_2O$	White, red, other colors	Most common ore of aluminum
2. Calcite	$CaCO_3$	White or colorless Bubbles when touched with acid (HCl or vinegar) With impurities: gray, red, green, blue	In manufacture of lime, plaster, cement Chief component of limestone and marble
3. Chalcopyrite (Copper pyrite)	$Cu_2S \cdot Fe_2S_3$ *or* $CuFeS_2$	Brassy yellow If tarnished, dark with rainbow hues	Abundant, valuable ore of copper
4. Cinnabar	HgS	Scarlet to brownish-red	Principal ore of mercury
5. Feldspar (Orthoclase)	$KAlSi_3O_2$	Colorless, white, gray, pink, red	Very common; used in manufacture of porcelain
6. Galena	PbS	Very heavy—lead gray	Chief source of lead
7. Gypsum	$CaSO_4 \cdot 2H_2O$	Usually white or colorless	Used for production of Plaster of Paris
8. Halite	$NaCl$	White or colorless	Used in cooking; a preservative; used in chemical industry; ordinary table salt
9. Hematite	Fe_2O_3	Brick red to steel gray, iron black	Most abundant ore of iron
10. Magnetite	Fe_3O_4	Black, magnetic	Valuable iron ore
11. Olivine	$(Mg,Fe)_2SiO_4$	Olive to yellowish green	When transparent, may be used as gem
12. Pyrite (Fool's Gold)	FeS_2	Brassy-yellow	One source of sulfur in manufacture of sulfuric acid
13. Quartz	SiO_2	Colorless to white—many varieties colored by impurities	As ornamental stone; as abrasive; in manufacture of glass, porcelain; in paints
14. Serpentine	$H_4Mg_3Si_2O_9$	Yellowish to dark green	May be used as building stone
15. Sphalerite (Zinc Blend)	ZnS	Commonly brown Other samples may be colorless, yellow, brown, green, red, or black	Most important source of zinc

U.S. Geological Survey

A glacier of solid ice grinds slowly and steadily down a canyon. It is a powerful agent of erosion in mountains where the weather is cold enough for it to form.

and came roaring down the mountain into a valley 3,000 feet below. The rock spread in a sheet across the valley, wiped out the town of Frank and killed 70 people. In these types of erosion, known as *mass wasting,* gravity is the moving force. Geologists believe that given sufficient time, mass wasting alone would eventually reduce the continents to smooth plains.

Glaciers. In regions where the climate is cold, more snow may fall than ever melts. The snow piles up. Under the influence of moisture and pressure the lower part of the snow mass changes to ice. When the mass becomes deep enough, usually 100 to 150 feet, it begins to creep slowly downhill to thus form a *glacier.* Moving glaciers are powerful agents of erosion. They plow large chunks of rock loose and transport them downhill. They act as a huge file making long scratches and grooves in the rock over which they pass. Some glaciers flow down mountain canyons; others are large ice sheets such as those found today in the polar regions. Geologists believe that most of Canada and the northern part of the United States were at one time covered by a huge ice sheet. This moving ice sheet was probably responsible for the thousands of lakes throughout northern United States and Canada, for the large boulders strewn over the surface of New England and eastern New York, and for the present location of the Ohio and upper Missouri rivers.

Wind. Wind not only moves quantities of soil in sand and dust storms, but it also wears away exposed rocks by blowing sand against them. The unusual rock formations on page 71 were produced by wind erosion.

Gravity, water, wind, and glaciers are slowly leveling the earth's surface. If there were nothing to counteract this leveling process, the oceans would eventually cover the continents. Fortunately for man, there are other forces at work.

INCREASING THE LAND SURFACE

Four-fifths of the total land surface of the globe is made up of sedimentary rocks. In the walls of the Grand Canyon they are exposed to a depth of 4,000 feet. They form the towering cliffs and peaks of Glacier National Park. They contain important mineral fuels such as oil, natural gas, and coal. The deepest oil wells have not penetrated through them. In fact, sensitive measuring instruments indicate that sedimentary rocks extend 30 to 40 thousand feet in some places. *Sedimentation,* meaning the process of depositing sediment, is probably the most important action tending to increase the land surface.

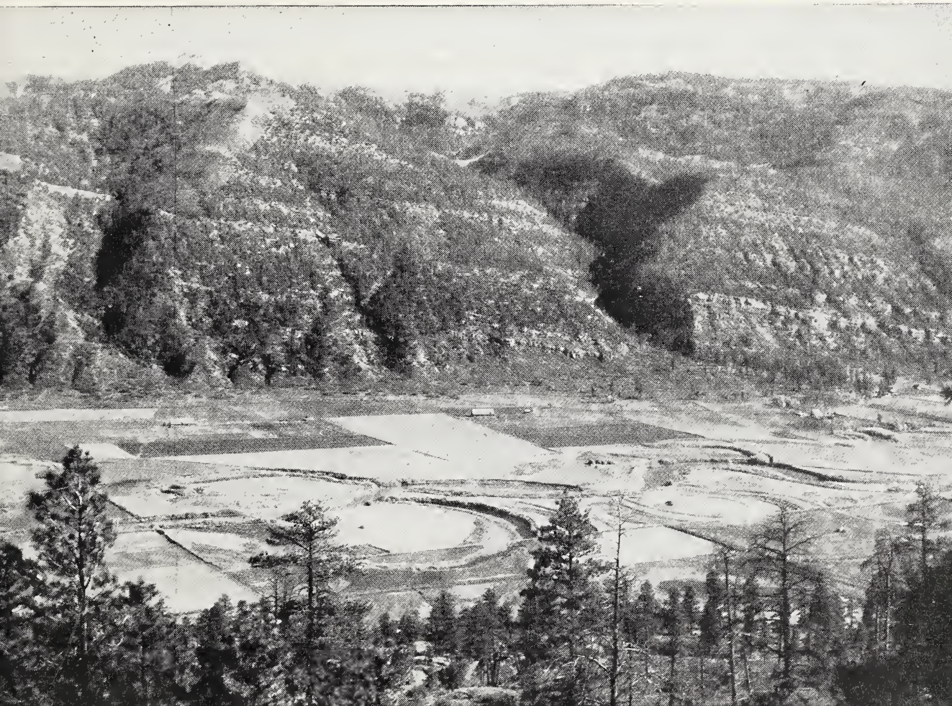
In addition to the type of sediment

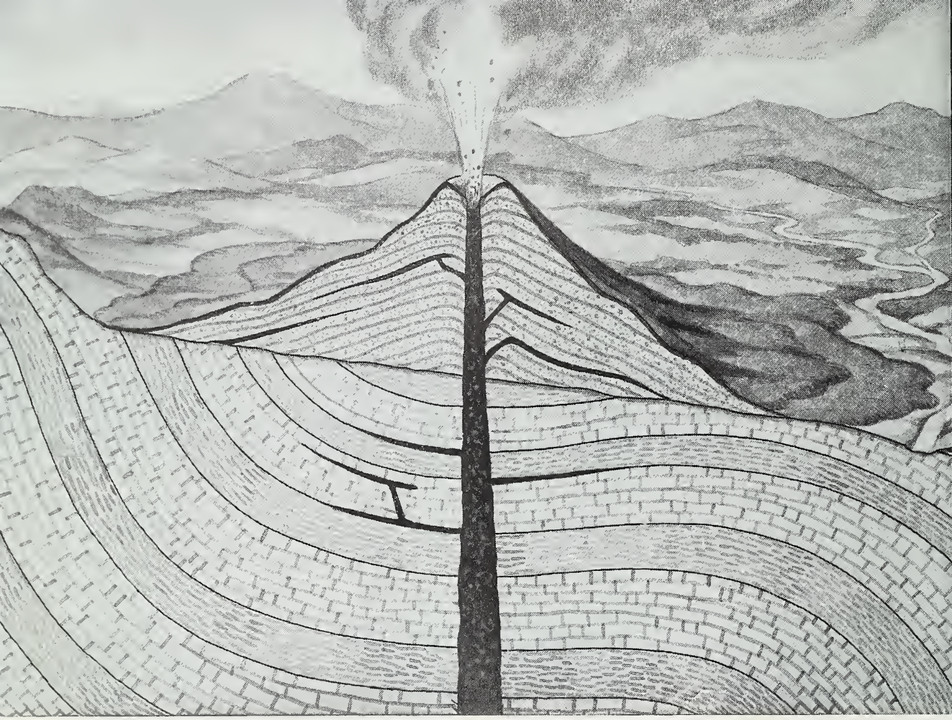
described on page 75, other kinds of sediment help to increase the land surface. Vast salt beds, estimated to contain 30,000 billion tons of salt, have been formed by the evaporation of water from ancient seas which no longer exist. Throughout the ages the sea has been populated with tiny plants and animals. Their life processes are responsible for the formation of calcium carbonate ($CaCO_3$) which, together with the solid parts of their bodies and the shells of larger sea animals, are laid down in vast deposits eventually to form limestone. Sometimes the remains of plants and animals living during a period of sedimentation are preserved so well their form can be clearly seen. These remains are called *fossils.* Scientists called *paleontologists* study fossils to determine the kinds of plants and animals that lived on the earth ages ago. Finally coal, to be studied in the next problem, has resulted from sedimentation.

Volcanoes. The smallest volcano is no larger than a beehive, the largest, the massive 19,600 foot Cotopaxi in Ecuador, South America. Many peaks of well-known mountain ranges are, or have been, volcanoes. For example, in the Cascade Range in western United States, Mt. Baker, Mt. Rainier, Mt. Hood, and Mt. Shasta are inactive volcanoes; Mt. Lassen is the only active volcano in the United States.

A valley of fertile soil in the mountains. Weathering breaks up the mountains and water carries the eroded material down the steep slopes until it reaches the level plain. Here the soil particles are deposited to form a fertile valley, called a *flood plain.* Note how the river winds back and forth across the flood plain.

U.S. Geological Survey





Volcanoes are formed when molten rock, called *magma*, from several miles below the surface of the earth is forced out at the surface through a deep crack in the earth. As the magma leaves the earth it is called *lava*. This represents one type of volcano in which the layers of lava from former eruptions have built up a cone around it.

Volcanoes may eject gases, melted rock called *lava,* and solid material. Steam is usually given off in huge quantities and is probably the greater part of the gaseous eruption. It is estimated that Parícutin, a recently formed volcano in Mexico, discharged about 16,000 tons of steam per day, along with 100,000 tons of lava, at the height of its activity. Other gases often present are hydrogen sulfide (H_2S), sulfur dioxide (SO_2), carbon dioxide (CO_2), hydrogen (H_2), hydrogen fluoride (HF), and hydrogen chloride (HCl).

The solid material ranges in size from dust particles so small that they stay in the air for years to masses of rock weighing tons. The explosive force of some volcanoes is astounding. Krakatoa, in the United States of Indonesia, blew a cubic mile of dust as high as 15 miles when it erupted in 1883. The dust was carried by air currents to all parts of the world. In 1930 the volcano Stromboli, located in the Aeolian Islands north of Sicily, hurled 30 ton rocks a distance of two miles.

Although present-day volcanoes build up the land area immediately around them, the lava flows today are small compared to some of those of the past. One gigantic lava flow produced the Columbia Plateau in northwestern United States which covers parts of Washington, Oregon, and Idaho. It is about 200,000 square miles in area and is known to be 4,000 feet deep in some places. It must have been a lava flow on a truly grand scale!

THE EARTH'S CRUST

Although man likes to think of the earth as "terra firma," there is considerable evidence to show that large portions of the land move slowly up or down, sometimes increasing, sometimes decreasing the land area. Tremendous internal pressures, the source of which is not fully understood, cause the surface to bend, fold, and sometimes to break open with a sudden shifting of the earth on each side of the break. Movement of the earth's crust, whether vertical or horizontal is known as *diastrophism*.

Vertical changes. Marks placed on the shoreline show that the countries bordering the Baltic Sea are slowly rising. At some places the rate is as much as 3 feet in 100 years. It is thought that parts of Sweden and Finland are as much as 900 feet higher than they were at the end of the last ice age. On the other hand, it is believed that many of the islands off the Maine coast are the tops of hills of former land surface. They became islands when the land sank and allowed the sea to flood river valleys.

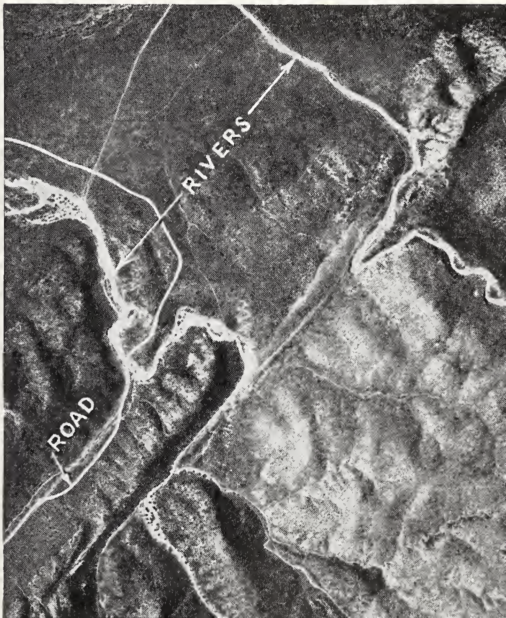
A large-scale vertical change is presently occurring in the Great Lakes region of the United States and Canada. Measurements show that the land to the north and northeast of the lakes is rising 5 inches per 100 miles each 100 years. If this rise continues, in some 1,600 years the lakes will flow to the ocean by the Chicago and Mississippi rivers rather than by the St. Lawrence River as at present.

The rocks in the lithosphere are not a solid mass but have cracks through them in many directions. When pressure on a layer of rock becomes great, part of the layer on one side of the crack may slip past the other part, thus forming a *fault*. Formation of new faults, or further sudden slipping along old faults, is one of the major causes of earthquakes.

Earthquakes. An earthquake is a vibration of the lithosphere started by some sudden jarring, quite like the vibrations of a bell after being struck a sharp blow. The earth suddenly shakes, buildings fall, and in cities water and gas lines are broken. Fires

An air view of the San Andreas fault in California. The shock waves caused when its rocky sides slid past each other killed hundreds of people. Note how river beds have shifted along the fault.

U. S. Forest Service

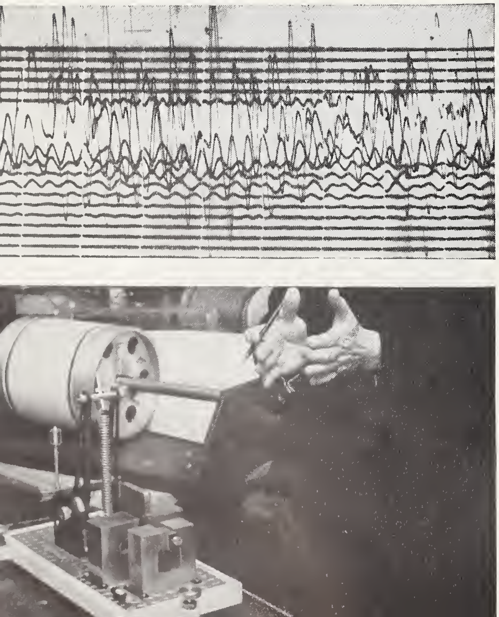


break out and rage unchecked through the city. Many people are killed or left homeless. The great earthquake in Tokyo, Japan, on September 1, 1923, killed some 140,000 people and resulted in property damage of about 3 billion dollars. One scientist estimates that at least 13 million people have been killed by earthquakes in the course of four hundred years. It is no wonder that man considers earthquakes among the greatest of natural disasters.

Although it is well known that earthquakes are associated with volcanic activity, the major earthquakes result from faulting. The great San Andreas fault, which can be traced along the earth's surface for 600 miles, passes near San Francisco. A sudden movement, as much as 21 feet in some places, along this fault caused the disastrous earthquake on April 18, 1906, in San Francisco.

The drum in this seismograph rotates steadily so that a pen draws a line on a sheet of paper attached to the drum's surface. When there are no earth vibrations, the line is straight; when the earth vibrates, the lines are jagged. Both types of line are in the sample record below.

Fordham University



If you place a small rock on a board on the floor and strike the board a sharp blow with a hammer, the rock will leap many times the distance the board moves. In a similar manner, objects on the earth's surface may be thrown several feet by the passing of a vibration from an earthquake, even though the earth actually moves only a fraction of an inch.

Scientists record the vibrations from earthquakes on an instrument called a *seismograph*. Seismograph records show that earthquake waves travel great distances through the earth before they die out. Studying these records from various parts of the world is one approach toward determining the structure of the earth's interior by the *if—then* method.

Although much is known about the causes and the effects of earthquakes, the conditions necessary for them to occur are so complicated that little hope is held for being able to predict their coming with accuracy. Man's best protection seems to lie in constructing buildings that will withstand the shocks and taking precautions to safeguard water systems so that the fires which often result from earthquakes can be controlled.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending that best completes each statement.

1. The slow process by which rocks are broken down is (a) sedimentation (b) erosion (c) weathering (d) creep.
2. A rock which has been changed by

heat and pressure is classed as (a) sedimentary (b) metamorphic (c) igneous (d) limestone.

3. The most important action tending to increase land surface is (a) faulting (b) lava flow (c) mass wasting (d) sedimentation.
4. The most abundant element in the atmosphere is (a) O_2 (b) Fe (c) Si (d) N_2.

PROBLEM 2. How are useful materials obtained from the earth?

MINERAL RESOURCES

The construction of modern buildings, automobiles, airplanes, and television sets, as well as the production of much of man's food, requires materials obtained directly from the earth. Since these materials must be mined, they are called *mineral resources.*

There are two classes of mineral resources, the *metallic* and the *non-metallic*. Metallic deposits are those containing metals such as iron (Fe), copper (Cu), aluminum (Al), platinum (Pt), gold (Au), and silver (Ag). They are important because of the wide use man makes of the metals they contain. The non-metallic deposits include mineral fuels such as coal and oil, building stones, cement materials, gems, and important industrial chemicals such as salt (NaCl) and sulfur (S).

To maintain a high standard of living, such as that in the United States, mineral resources must be used at a tremendous rate. In 1950 an average of 1,260 pounds of steel was used for every person in the United States, while in India the average was less than 10 pounds. In the same year, the United States used as much energy per person (not considering food) every 2 days as was used in India during the entire year. About 92 per cent of the energy used in the United States came from coal, petroleum, and natural gas, which took millions of years to form. Although they may be forming at certain places on the earth, they are formed so slowly that man must depend upon the present deposits for his supply. Coal, oil, and other materials which require millions of years to replace are *fixed* mineral resources.

There is every indication that the rate at which the earth's materials are used will increase rather than decrease. Taking into consideration the probable increase in standard of living and population, one scientist estimates that the supply of coal, petroleum, and natural gas in the United States may last anywhere from 75 to 250 years. Although unforeseen factors may make the fuels last longer than 250 years, it seems certain that, unless new sources of fuels are discovered and put to use, these fuels will one day be exhausted.

NON-METALLIC MINERAL RESOURCES

Formation of coal. Since no one has been able to observe coal being formed, scientists have attempted to explain its formation by the *if—then* method. Reviewing the method scientists have used in determining how coal was formed may help you get a better understanding of the *if—then* method of solving problems. The following facts were discovered by direct observation:

1. Coal contains carbon, hydrogen, oxygen, nitrogen, sulfur, and some mineral substances. Many of these chemical elements are also found in plants.

2. Coal often contains imprints of leaves of giant tree ferns similar to those found in tropical jungles of today.

3. *Methane gas,* called "fire-damp," is often found in coal mines. When plants decay in marshes or bogs, methane gas is formed.

4. Thin slices of some kinds of coal look very much like thin slices of plants when examined under a microscope.

Scientists then said that *if* the above facts are true, *then* it can be concluded that coal was probably formed from plants which grew in a tropical climate.

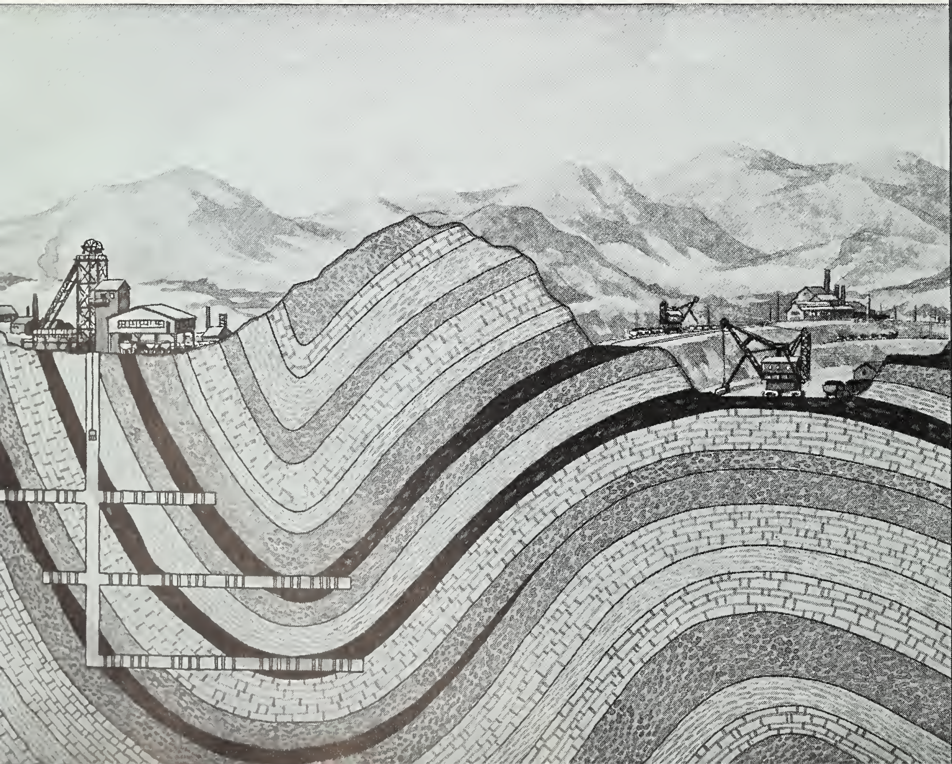
Other observed facts about coal are:

1. Coal is found in layered deposits, or seams, often called *veins.*

2. Coal is found near shale, sandstone, and limestone, which are sedimentary rocks.

3. The largest coal-bearing regions of the earth are located where it is be-

To reach buried coal veins, as shown at the left, a deep shaft is dug. Tunnels supported by pillars extend out from the shaft to enable miners to get more coal. If the coal is near the surface, as shown at the right, the soil is stripped off with power shovels so that the coal can be dug. This is called *strip mining*.



lieved that swamps once existed and were later buried under sediment.

4. Plant materials have been put under high pressure and temperature in the laboratory and changed into a black substance closely resembling coal.

Scientists again said that *if* these facts are true, *then* it could be further concluded that plants were probably deeply buried under sediment and as a result were changed to coal.

At least four distinct materials are formed in the process by which plants are changed to coal. The first substance is known as *peat*. As plants die, they fall to the bottom of a bog or swamp, where they partially decay. The partly decayed plants pile up and form a brownish-black layer of peat. In some bogs, peat is 40 feet thick. Peat can be dried and burned for fuel, but it does not give as much heat as coal. When peat bogs, or something similar to them, are deeply buried under sediment, the partly decayed plant material slowly changes into a brown substance known as *lignite*. Lignite is one type of coal. In time, pressure changes some of the lignite into soft, or *bituminous*, coal. When soft coal is subjected to greater pressure, as a result of changes in the earth's surface, it becomes hard coal, called *anthracite*. Thus anthracite might be considered a metamorphic rock.

Coal mining. Coal is mined in various ways. Where the layers of coal are found beneath a shallow layer of soil, strip mining is done. Much coal lies at considerable depth below the surface in seams varying from a few inches to about 60 feet in thickness. Deep holes, called *shafts*, are dug down to the seam of coal. The way some of the processes of coal mining are carried on is shown on page 84.

Philip Gendreau, N.Y.

Large timbers are placed in mine tunnels for safety. Without them the walls might cave in, endangering the workers and making it impossible to work the mine.

Petroleum in the earth. *Petroleum*, another important material obtained from the earth, is a dark-colored oily mixture of many different substances. Gasoline, kerosene, fuel oils, *lubricating oils, paraffin*, grease, and *asphalt* are a few of the important substances obtained from petroleum. Petroleum, taken from the earth usually as oil or *crude oil*, is generally found in sedimentary rocks. Salt water and materials from plants and animals that live in the

C. F. Lockwood from Cushing

An open-pit iron mine in the Mesabi Range in Minnesota. Note how the mine is terraced and that the terraces are gradually being removed.

sea are often found with it. These facts have led scientists to conclude, by the *if—then* method, that petroleum was formed from the plant and animal life of the sea. The process by which it was formed is not entirely understood. It seems probable, however, that great pressure and high temperature played a part. A gas, called natural gas, is also produced in the petroleum-forming process and is often found with it in the earth.

Because the sedimentary rocks, such as sandstone, have a *porous* or sponge-like structure, petroleum, gas, and sea water accumulated in them and have moved upward through them much as ink moves along a blotter. These substances became trapped in dome-shaped structures, or pockets, which were formed in the lithosphere as earth forces wrinkled and twisted it. To obtain the petroleum from these pockets, wells must often be drilled thousands of feet below the surface of the earth.

Drilling for oil. Drilling an oil well is an expensive undertaking. It is therefore desirable to find oil-bearing pockets in the earth before drilling a well. At first, and sometimes even today, oil men tried to locate oil by means of *divining rods* and other magical means. Needless to say, such methods are unreliable. Today oil companies employ geologists. These men have developed reliable scientific methods of locating rock formations in which petroleum is likely to be found.

Most oil wells are drilled with a *rotary* drill which bores a hole into the earth somewhat as a bit bores a hole in wood. The rotary drill is hollow. As it is twisted down into the earth, a constant stream of mud is forced through it. The mud keeps the drill cool, covers the sides of the hole to prevent cave-ins, and carries the rock cuttings from the drill up to the surface. As the hole is drilled, a steel pipe called a *casing* is forced into it. When the oil-bearing material is finally reached, a smaller pipe is lowered into the well. This pipe is sealed to the casing at the top so that oil cannot escape except through the small pipe. Valves to control the flow of oil and *gauges* to measure the pressure and amount of oil flowing through the casing are attached to the smaller pipe.

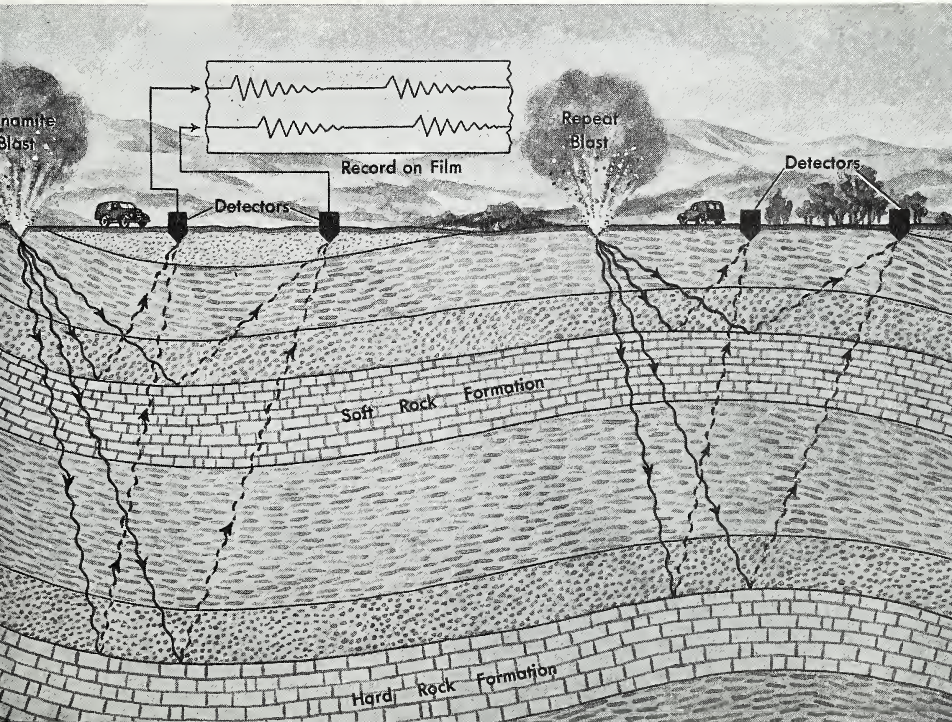
Most of the oil is found at great depths below the surface of the earth. Many oil wells in the United States are over 10,000 feet deep. With special instruments and apparatus, oil wells can be drilled straight down or curved, if necessary, to reach an oil structure.

Oil from shale. Much of the shale now exposed on the surface of the earth contains oil. Scientists believe that this oil was formed from the bodies of tiny plants and animals trapped in the mud that later became shale. Shale may thus be a good source of oil.

Rocks as fuel. The development of atomic energy has made available to man new fuel such as uranium and thorium, to be discussed in Unit 11.

Both of these elements are *radioactive* (see pages 504-505) and are found, like other metals, as minerals in the lithosphere. The presence of radioactive elements can be detected with an instrument known as a *Geiger counter*. The Geiger counter contains a special thin-walled, glass tube (Geiger tube) which is affected by radioactive substances. When the Geiger counter is near a radioactive substance, the tube reacts in such a way that the pointer of a needle moves, clicks are heard over a radio loudspeaker, or lights flash. Since Geiger counters give an indica-

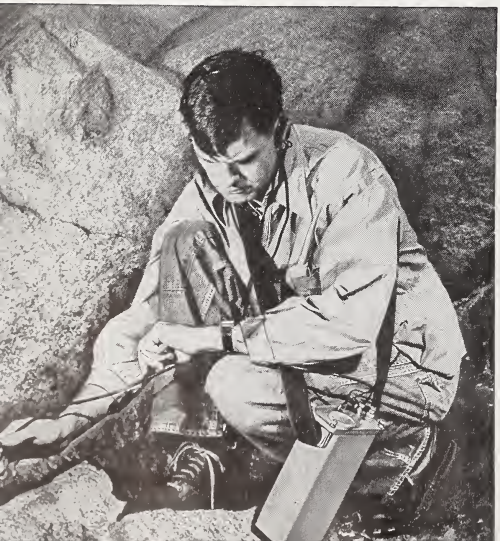
In one scientific method of studying the interior of the earth, a dynamite blast sends energy waves into the earth. They are reflected back from rock formations to sensitive detectors. Hard formations make large jogs on a recording film, while soft formations make smaller ones. The time between the blast and the arrival of the reflected wave at the detectors is an indication of depth.



tion of the amount of radioactive substance near the Geiger tube, they are useful in locating deposits of radioactive elements such as uranium and thorium. The deposits of uranium and thorium in the United States that can be mined under present conditions are estimated at 50,000 tons. With mining methods yet to be developed, this figure will probably be increased by another 500,000 tons. If this fuel can be used as efficiently as coal has been, it is enough to supply the present energy requirements of the United States for 1,000 years. Furthermore, if 15 per cent of the uranium and thorium present in average granite could be used, all the granite of the continents would become fuel. One ton of granite would produce about the same amount of energy as 7 tons of coal. If granite could become fuel on the above basis, it is estimated that the supply would furnish the world's needs for energy for thousands, perhaps even millions, of years to come. Atomic energy, if it were used for peaceful purposes, would open new vistas for mankind.

Using a Geiger counter to check radioactivity. A special electronic tube held near the rocks causes clicks to be heard in the earphones at a rate varying according to the amount of radioactivity.

Tracerlab, Inc.



NON-METALLIC MINERAL RESOURCES OTHER THAN FUEL

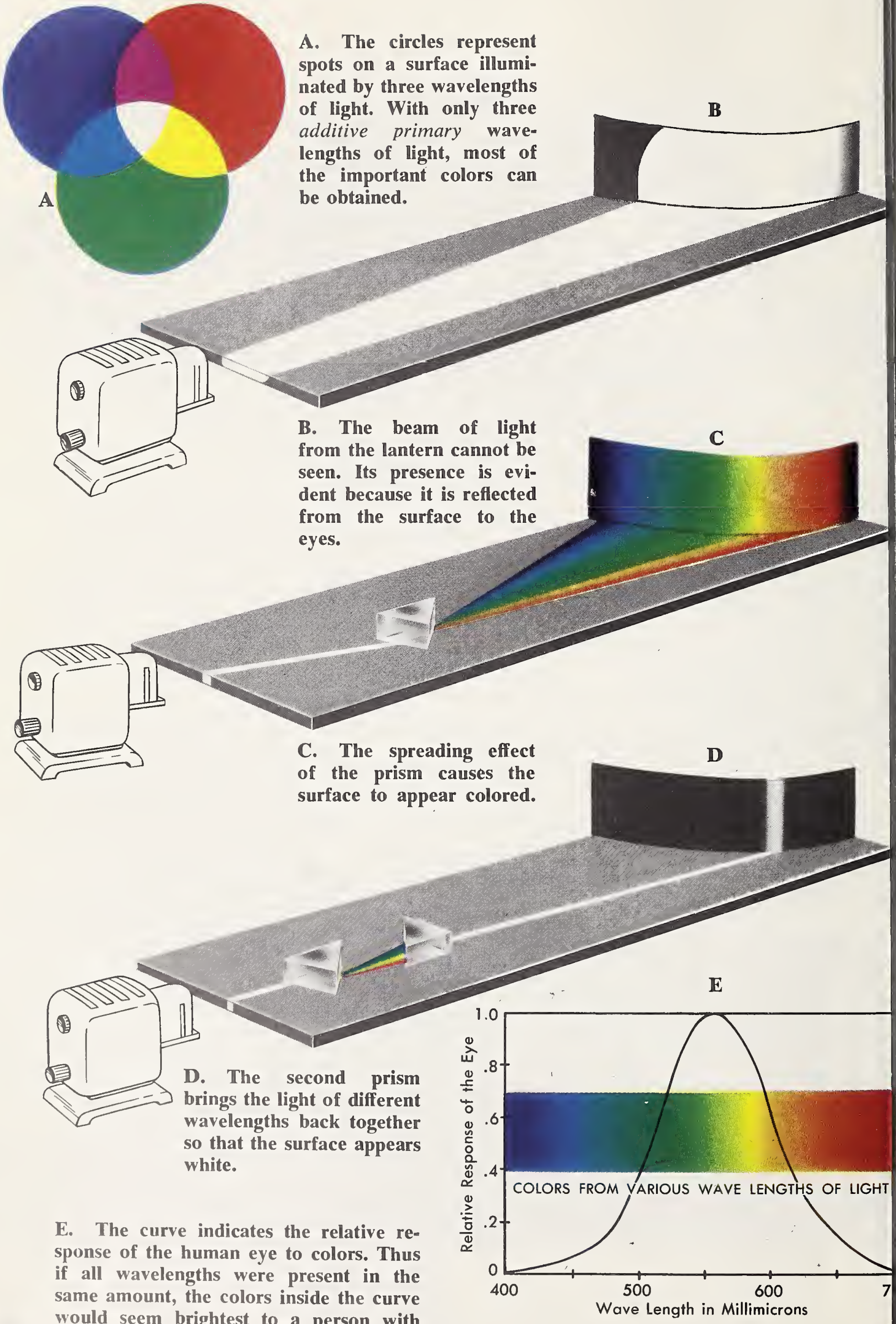
The next time you see a one-ton truck, make a mental note of how much you think it holds. Then multiply that amount 5 times and you will have the amount of non-metallic minerals, aside from fuels, used per person in the United States in 1949. These minerals include rock used for buildings and highways, salt and sulfur for industrial use, and gems for personal and industrial use.

Rocks. Sandstone, limestone, granite, and marble are most widely used for building purposes. They are often obtained from open pits, known as *quarries,* similar to that shown on page 89. The most common mineral known is silicon dioxide (SiO_2). Ordinary sand is mostly SiO_2. Large quantities of SiO_2 are needed for highways, buildings, and dams, for making glass, as well as for many other industrial uses. SiO_2 is readily available from the many deposits near the earth's surface.

Salt mining. You have probably heard the saying that a certain person is "not worth his salt." This expression is supposed to have originated in early times when salt was very precious and workmen were paid with salt. Salt is an essential part of our food. In the United States the average person consumes about 6 pounds of salt a year. In addition, salt is used more extensively than any other material in the manufacture of chemicals. During one

Photo by Archie W. McKeown

Logs sink until they displace a volume of water which weighs as much as they do. The logs float at this level and can be towed to the sawmill.


A
B
C
D
E
1.0
.8
.6
.4
.2
0
Relative Response of the Eye
COLORS FROM VARIOUS WAVE LENGTHS OF LIGHT
400
500
600
7
Wave Length in Millimicrons

A. The circles represent spots on a surface illuminated by three wavelengths of light. With only three *additive primary* wavelengths of light, most of the important colors can be obtained.

B. The beam of light from the lantern cannot be seen. Its presence is evident because it is reflected from the surface to the eyes.

C. The spreading effect of the prism causes the surface to appear colored.

D. The second prism brings the light of different wavelengths back together so that the surface appears white.

E. The curve indicates the relative response of the human eye to colors. Thus if all wavelengths were present in the same amount, the colors inside the curve would seem brightest to a person with normal eyes.

year more than thirteen and a half million tons of salt were produced.

Salt beds were deposited from the water of seas. Large areas of the United States were covered by these waters during ancient times. Some of the resulting beds are more than 600 feet thick. One of the largest beds is located in parts of three states, southwestern Kansas, western Oklahoma, and northern Texas. It covers an area of about 20,000 square miles and in some places is more than 400 feet thick. Other large salt beds are found in Michigan and New York. A salt mine has been discovered in Nevada that apparently was worked by the Indians over three thousand years ago.

If salt beds lie near the surface, the salt is mined in much the same manner as coal. When a salt bed is buried as deep as 2,000 feet below the surface of the earth, pipes are extended through a hole drilled into the salt bed. A short pipe extends to the top of the salt bed. Other pipes extend farther into it. Water forced through the short pipe dissolves the salt. The *brine* that is formed is pumped to the surface through the other pipes. The water is then evaporated from the brine, and the salt is made ready for use.

Sulfur mining. Sulfur, another material obtained from the earth, is an important chemical element. It is used in manufacturing sulfuric acid, which has a great many industrial uses. In powder form, sulfur is dusted over plants to control certain plant diseases. Sulfur is an essential material in the manufacture of automobile tires.

One of the largest sulfur-mining regions in the United States is in southern Texas and Louisiana along the Gulf of Mexico. Sulfur was discovered in this region toward the end of the nineteenth century while an oil well was being drilled. The sulfur was 450 feet below the surface of the earth. Attempts to dig mine shafts down to the deposit were unsuccessful. Eventually a scientist, Dr. Herman Frasch, devised a process for mining the sulfur by using three pipes. By the Frasch method water heated to about 330°F is forced through one pipe down to the sulfur bed. The hot water melts the sulfur which collects as a pool in the lower part of the bed. Compressed air in a second pipe driven into the pool forces the melted sulfur to the surface through a third pipe. It is then cooled and stored in large rectangular blocks about 250 feet wide, a quarter of a mile long, and 50 feet high. There are usually about 4,000,000 tons of sulfur stored above ground in this form. This is sulfur enough to last the United States for about fifteen months.

Vermont Marble Company

An open pit marble quarry at Roxbury, Vermont. Note the use of machines to lift the large marble block from the floor of the quarry.

METALLIC MINERAL RESOURCES

Metals have become so necessary to our present-day living that it would be very difficult to get along without them. Airplanes, automobiles, and other vehicles of modern transportation would not exist if there were no iron, copper, and aluminum. Tall skyscrapers and long bridges are made strong by steel, which is manufactured from iron. The telephone, radio, and television could never have been developed without metals.

Metals from the earth. Most valuable metals are found as one element in the compound forming a mineral (see page 83). If the valuable metals can be separated at a profit from the rock containing them, the rock is known as *ore*. Whether a rock is an ore may depend more upon the price for which the metal can be sold than upon the amount of metal present. For example, tons of rock which were *not* ore when gold brought $20.67 an ounce became ore overnight when gold was raised to $35 an ounce in 1934.

It is believed that some metals now obtained from the earth were originally scattered throughout hot melted rock material below the surface of the earth. They may have been collected or concentrated in ore deposits in several ways. As the melted rock was forced toward the surface of the earth, it cooled and became hard igneous rock. During the cooling process, heavy metals like nickel and platinum settled into more concentrated deposits within the rock. Other metals, such as iron, copper, lead, and tin, may have been concentrated as minerals in certain places by this process: These minerals in vapor form were mixed with the gas escaping from the earth in volcanic regions, and were slowly deposited along the surface of cracks and openings in the rock through which the gas passed. In time the openings in the rocks were completely filled, forming the present deposits of ore, called veins. Water has also aided in collecting and concentrating ores. The water probably acted in two ways. First, it dissolved the minerals from the rocks which held them in very small amounts. Then as it moved through cracks and crevices in the earth, the dissolved minerals were deposited along the pathway the water took. Second, as the igneous rocks, pushed up in forming mountains, were worn down, the ores they contained were washed into the stream beds where they settled out of the water and formed a rich ore deposit.

Metal mining. The method used in mining a particular metal depends upon the form in which the ore has been deposited. If the ore is in buried veins, tunnels are driven into the earth and the ore is removed much as coal is mined. In South America some metal mines have been dug deeper than one mile into the earth. If a metal like gold is contained in gravel and sand which has been deposited by a stream, *hydraulic mining* can be used. In hydraulic mining, water under high pressure loosens the sand and gravel, which are then washed with water. Since gold is heavy, it tends to settle and can then be easily collected.

Some ores, especially iron ore, occur in large bodies near the surface of the earth. In such places *open pits* are dug into the body of ore. One of the large open-pit iron mines is located in the

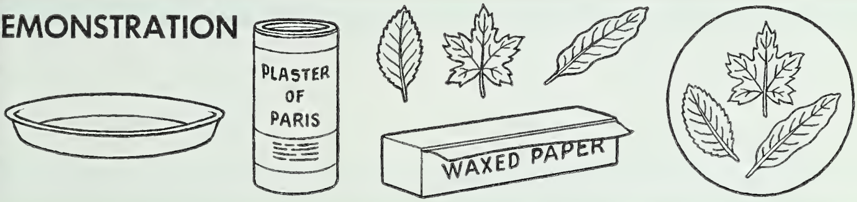
Mesabi Range near Lake Superior. Large deposits of iron ore near the surface are thought to have been concentrated there by the action of water. The water dissolved most of the substances with which the ore was originally mixed, leaving the insoluble ore behind to form the iron-ore bed as it is now found.

The methods used to take metals from their ores and purify them for use will be discussed in Unit 13.

SUMMARY

The earth is a vast storehouse of useful materials. From the storehouse man obtains construction materials, fuels, metals, and chemical elements essential to modern living. He has developed successful methods for obtaining large quantities of these materials, but our natural supply of some of them may soon be exhausted. It is therefore important that our fixed natural resources be used carefully and wisely.

DEMONSTRATION



Generalization to be demonstrated. Prehistoric plants can be identified from their fossils which are found in sedimentary rocks.

What you need. Plaster of Paris; waxed paper; leaves from several different kinds of plants; water; and a small pie tin.

What to do. Make a mixture of water and plaster of Paris about as thick as syrup. Cover the bottom of the pie tin with waxed paper and pour in about one fourth of an inch of the mixture. Cover it with different kinds of leaves. Cover the leaves with the remainder of the plaster of Paris. Set aside to dry. After it has dried, separate the two layers.

What to observe. What is the appearance of the surface of plaster of Paris that was next to the leaves?

What does it mean? If you saw only the imprint of the leaves on the plaster of Paris, could you tell from what kind of plant they came?

How can scientists who study fossils tell what prehistoric plants looked like?

A basic assumption in this demonstration. The plaster of Paris block in this demonstration was affected by the leaves in a manner similar to the way sedimentary rocks have been affected by leaves in the past.

TEST YOURSELF

Write your answers in the proper place on your answer sheet.

1. Copy the names of each of the following materials on your answer sheet and after each write **a** if it is a metallic resource and **b** if it is a non-metallic resource.

coal	salt
uranium	sulfur
oil	iron

2. On your answer sheet write the letters of the following items which are considered indirect evidence that coal may have been formed from plants.
   - a. Pieces of slate found in coal
   - b. Leaf prints found in coal
   - c. Coal has to be mined
   - d. Fire-damp in coal mines
   - e. Structures seen in some coal with a microscope.

CHAPTER ACTIVITIES

SELECT HYPOTHESES

1. A considerable amount of coal is mined in and near the Rocky Mountains. Some of these coal mines are as much as 8,000 feet above sea level. Since coal is believed to have formed in areas that were once swampy and later covered by the ocean, one might wonder how it is possible for coal beds to be formed at such high altitudes. A number of possible hypotheses explaining the location of these coal beds follow. Write the letter of the hypothesis you think most reasonable on your answer sheet.

a. The ocean once covered the United States to a depth of 8,000 feet and has since dropped to its present level.

b. The coal beds were formed at a much lower altitude and were raised to their present level when the mountains were formed.

c. The earth was at one time much warmer than it is today, and the coal-forming plants grew in mountain swamps.

d. The coal was formed from forests which were covered by lava from volcanoes.

UNIT ACTIVITIES

APPLY WHAT YOU HAVE LEARNED

In Part 1 below there is a short description of the Dead Sea, each sentence of which is numbered. Read the description carefully. In Part 2 there are five questions about the Dead Sea, followed by four generalizations studied in this unit. In the proper place on your answer sheet, write the number of the sentence and the letter of the science generalization which can answer each question.

Part 1

(1) The Dead Sea in southern Israel is 47 miles long and from 5 to 10

miles wide. (2) Its surface is almost 1,300 feet below the level of the Mediterranean Sea. (3) The Dead Sea has several inlets, among them the Jordan River, but apparently has no outlet. (4) In spite of its many inlets, the water level of the sea does not change. (5) Each ton of water in the Dead Sea contains 187 pounds of chemicals as compared to 31 pounds in a similar amount of water from the Atlantic Ocean. (6) Bulk for bulk, its water is heavier than the human body. (7) It is almost impossible for a bather to sink in the water even if he tries. (8) The water is deep blue in color, but has a disagreeable taste caused by the chemicals dissolved in it.

Part 2

QUESTIONS

1. Why is the Dead Sea so salty?
2. Why would the air pressure at the surface of the Dead Sea be greater than at the surface of the Mediterranean Sea?
3. Why can't a bather sink in the water of the Dead Sea?
4. How does the water level in the Dead Sea change?
5. Why can a boat carry a bigger load on the Dead Sea without sinking than it can carry in the Atlantic Ocean?

GENERALIZATIONS

a. Material dissolved in water is left behind when the water evaporates.

b. Any object is buoyed up with a force equal to the weight of the liquid it displaces.

c. Water evaporates from surfaces exposed to the air.

d. Air pressure depends upon the amount of air above the point where the pressure is measured.

REPORT ON THE EARTH'S MATERIALS

The following are suggested subjects for reports:

a. The ocean as a storehouse of chemicals
b. Methods of separating metals from their ores
c. Prehistoric animals of North America
d. Oil wells under the ocean
e. Hoover Dam
f. Precious stones from the earth
g. The use of oxygen in high-altitude flying
h. The La Brea tar pits
i. Making artificial diamonds
j. The seismograph
k. Famous caves or underground caverns
l. Geysers and hot springs

PLAN AND PERFORM ACTIVITIES

1. Devise a demonstration to show how such chemicals as aluminum sulfate (alum) can be used to clear muddy water.

2. Conduct an experiment to compare the effectiveness of washing soda and borax as water softeners. Plan your experiment in a manner similar to the experiment on pages 62-64.

3. Using a model boat, show how improper loading affects the safety with which the boat can be operated.

4. Perform a demonstration to show that a rock will lose more weight in salt water than in fresh water. Plan your demonstration in a manner similar to the demonstration on page 69.

5. Obtain a faucet from a local plumber and demonstrate to the class how a wornout washer can be replaced.

6. Many of the advertisements for synthetic detergents claim that no

scum is left on materials washed with them in hard water. You can gather evidence upon the accuracy of this statement in the following manner: Obtain three pieces of cotton cloth. Wash one of them in hard water with soap, another with a synthetic detergent, and the third in water alone. Rinse the pieces in clean water and examine them under the microscope when they dry. Look for scum attached to the fibers of each piece of cloth. Do your observations support the claims that have been made by the advertisers?

STUDY COMMUNITY SERVICES

1. Make a study of the water system in your community to obtain information about the following:
   a. The source of water
   b. Methods of treating the water
   c. System of distribution
   d. Cost to the consumer
   e. Use of home water softeners

2. Visit the local sewage disposal plant (if there is one in your community) and have the attendant explain how the sewage is treated.

READ ABOUT THE EARTH'S MATERIALS

The following are references which you may find helpful in increasing your understanding of the unit:

Carsen, Rachel L. *The Sea Around Us.* New York: Oxford University Press, 1951.

Informative story of the life history of the ocean.

Ellis, Cecil B. *Fresh water from the ocean for cities, industries and irrigation.* New York: The Ronald Press, 1954.

Explores the possibility of converting ocean water to fresh water.

Fenton, Carroll L., and Fenton, Mildred. *Rocks and Their Stories.* Garden City, N. Y.: Doubleday and Company, Inc., 1951.

With constant reference to photographs, the authors define the distinction between "rocks" and "stones" and discuss rocks and the minerals of which they are composed.

Freeman, Ira M. *All About the Wonders of Chemistry.* New York: Random House, Inc., 1954.

An excellent book which explains how chemistry began and how the theories of molecular combination and atomic structure evolved. The author also describes the applications of chemical knowledge in various fields.

Freeman, Mae, and Freeman, Ira. *Fun With Science.* New York: Random House, Inc., 1943.

Describes a number of air demonstrations that you will find interesting.

Johnson, Gaylord. *The Story of Earthquakes and Volcanoes.* New York: Julian Messner, Inc., 1938.

Clear explanation of causes of earthquakes and volcanoes, with demonstrations which you can do to obtain a better understanding of them.

Morgan, Murray. *The Dam.* New York: The Viking Press, Inc., 1954.

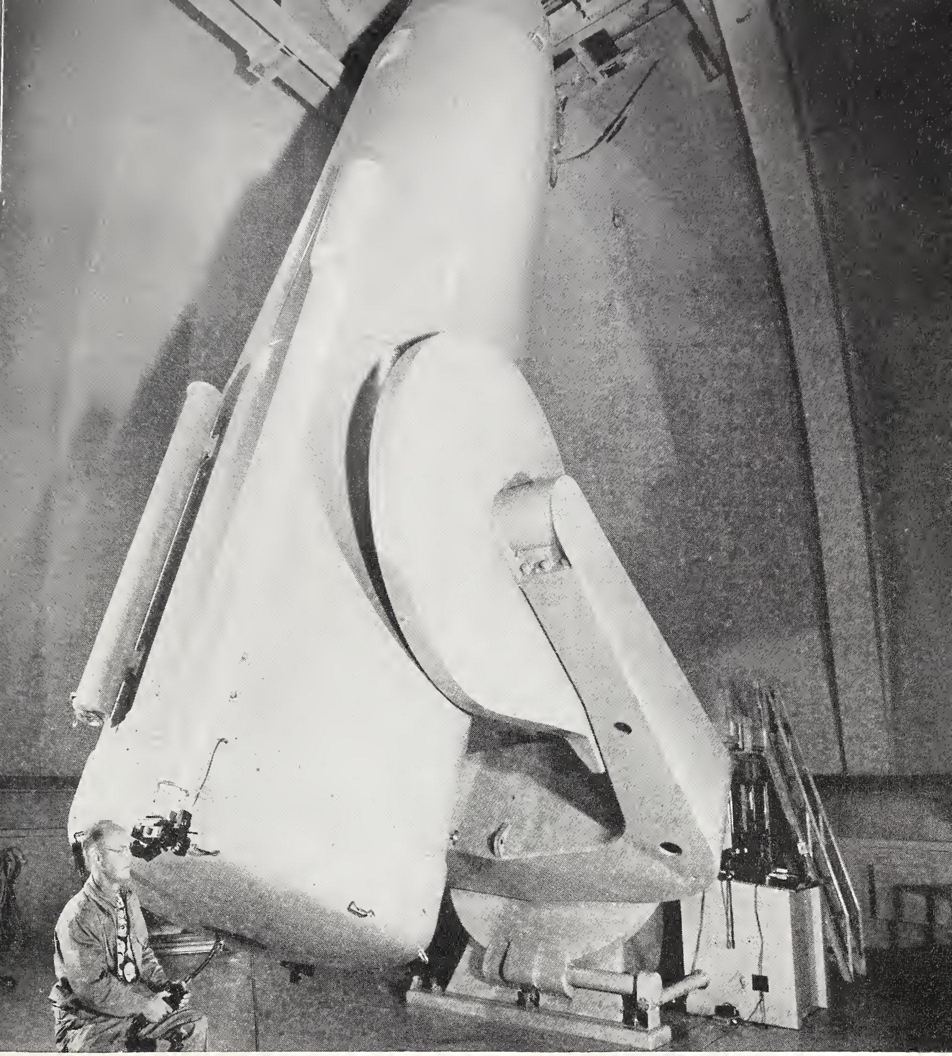
Story of Grand Coulee Dam from its daring inception. An exciting story of man and nature.

Riedman, S. P. *Water for People.* New York: Henry Schuman, Inc., 1952.

Discussion of water and its influence on life.

Wyler, Rose, and Ames, Gerald. *Restless Earth.* Abelard-Schuman, Inc., 1954.

This book explains the nature of volcanoes and earthquakes, how mountains are formed, the operation of a seismograph and the evolution of rocks. The explanations are clear and easy to read.



Palomar Mt. Wilson Observatory

The 48-inch Schmidt Telescope-camera which has been used in the Palomar Observatory in California since 1949. Larger sections of the sky can be photographed by this giant camera than was possible with other telescopes before it was invented by a German, Bernhard Schmidt.

unit 3 THE UNIVERSE

I AM a boy only thirteen years of age but if I had the opportunity to go into space I would jump at the chance," wrote Walter, one young reader of a series of articles on space travel.

Another, an older reader, wrote in reply to the same articles, "I predict that it will be impossible to produce men willing to let themselves be disembarked a thousand miles above the earth. To put it bluntly: no one is going to be that crazy."

The sun, moon, stars and the vast space between them have held great interest for many people. The mystery which for ages was associated with these bodies caused some people not only to fear them, but often to worship them as well. Even today, when we have more reasonable explanations of what the heavenly bodies are and how they affect the earth on which we live, there are those who still associate both mystery and fear with them.

From ancient times man has attempted to obtain a better understanding of the heavenly bodies. He has not been concerned as to whether the knowledge he obtained could be put to some practical use, but has wanted only to satisfy his curiosity by attempting to answer his many, many questions, such as: What's on the moon? Is there life on other planets? What are comets? What are stars? How do they come into being? Why do some of them blow up? What besides stars is there in space? How big is our universe? How is our universe arranged?

Although reasonable answers to some of man's many questions have been found, there are still many unanswered. For each question that is answered, many new questions are raised. So complex are some of them that many years of the life of one scientist may be spent in searching out bits of information which when put together supply only a part of an answer to one question. And so the fascinating search continues.

It is hoped that a study of this unit will help you to understand how ancient man came to have some of his ideas about the earth, sun, moon, and stars; how curious-minded men with instruments for observing these bodies have obtained more reasonable explanations of what they are; and, finally, what effect it is believed that these bodies have upon us here on the earth.

After studying this unit, you may be in a better position to decide whether you would like to go along with Walter.

Lick Observatory, Mt. Hamilton, California

The Andromeda Galaxy 4,500,000,000,000,000,000 miles away as photographed through a telescope. It is believed that this is a large system of stars similar to the Milky Way in which our world is located.

chapter 6 NATURE OF THE UNIVERSE

IF YOU should want to use one word that would include every living and nonliving thing in existence, you could use the word *universe*. The universe includes the earth and everything on it and also the sun, the moon, the *stars,* the *planets,* and every other heavenly body. In studying the first problem in this chapter, you will learn how it has been possible for man to make so many discoveries about the universe. In the second problem, you will learn about some of these discoveries. In this chapter, you will review what it has taken scientists hundreds of years to find out about the universe. You will learn about some of the problems they are still attempting to solve.

PROBLEM 1. How have discoveries about the universe been made?

EARLY IDEAS OF THE UNIVERSE

When man first began to observe his surroundings, the sun, moon, stars, and other heavenly bodies were there. The sun shone brightly upon him during the day. At night, when little else could be seen, he watched the moon and the stars in the heavens. Many questions about them came to his mind, and he attempted to find answers.

Early generalizations about the sun. The sun was probably the first of the heavenly bodies that roused man's curiosity. First, he was aware that the sun helped him live. It gave him light by which to see, and it warmed his body. He also observed that without sunlight plants did not grow and produce food for him. Second, he saw that the sun was dependable. He knew that just as surely as it set in the evening, it would rise the next morning. Finally, he believed the sun was everlasting. Man and other living things soon grew old and died, but the sun apparently neither grew old nor died. These observations led man to believe, rather naturally, that the sun possessed greater power than any human being and should be worshipped.

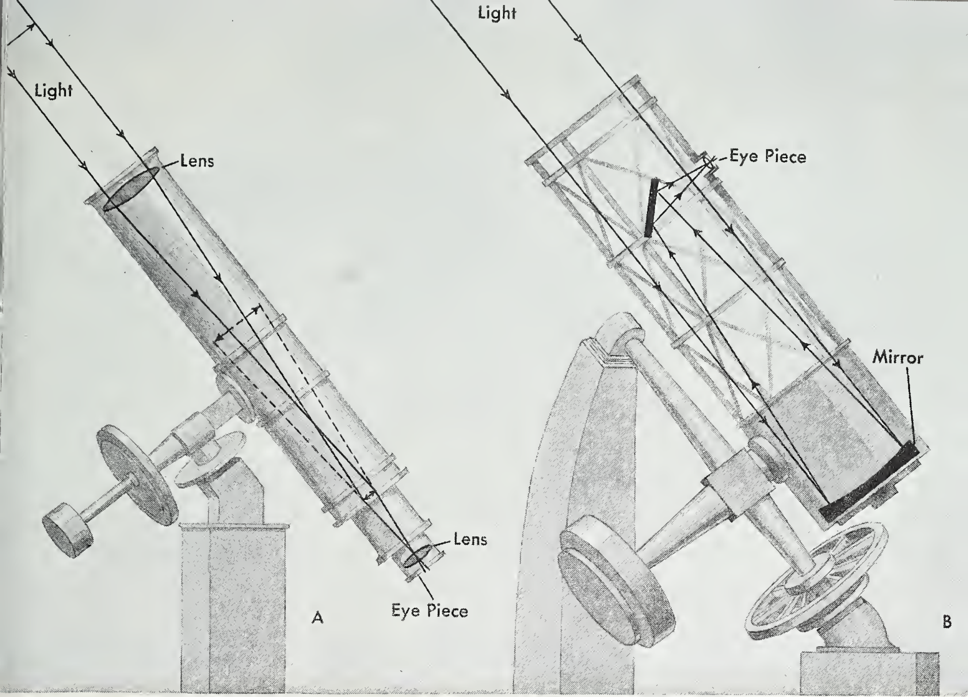
From astrology to astronomy. Early man observed that the stars, although they rose and set at night, remained fixed in the same order and arrangement. But he also observed that seven objects changed their positions within the field of stars. These he called *planets,* meaning "wanderers," because they moved about among the stars. He considered both the sun and the moon along with Mercury, Venus, Mars, Jupiter, and Saturn as planets. Today we know that they are different, and we no longer think of the sun and moon as planets.

He learned that he could predict the movement of the planets. He soon associated their movement with happenings in his life and therefore thought that by studying them he could predict events which he believed to be controlled by them. A study of the planets for the purpose of predicting events in the lives of human beings is known as astrology, and persons who carry on such studies are called *astrologers.*

The early astrologers made many correct discoveries about the positions and movements of heavenly bodies. For this reason, astrology is sometimes called the father of *astronomy.* Astronomy is the scientific study of all the bodies of the universe and deals only with observed facts and theories. Astrology is not a science because it is based upon many superstitions and unfounded beliefs.

Early generalizations about the earth. Curiosity also led man to ask questions about the earth upon which he lived. What was the position of the earth in relation to the rest of the universe, he wondered. He saw that while he was standing still, the sun rose in the east, crossed the sky during the day, and set in the west. The moon and the stars, too, moved across the sky. From his simple observations of these motions, man concluded that the sun, moon, and stars were moving around the earth, which was not moving.

He also asked, "What is the shape of the earth?" When he looked around in all directions, as far as his eye could



In the refracting telescope A, the front lens forms a small inverted image (smaller arrow) which is magnified (larger dotted arrow) by the lens in the eyepiece. In the reflecting telescope B, light is collected by the concave mirror and reflected by other mirrors into an eyepiece or a camera.

see, the earth seemed flat. Therefore he believed that the whole earth was flat.

Early instruments for observing heavenly bodies. Early astronomers had very few instruments with which to make their observations. They could therefore see only what was visible to the unaided eye, and they devoted their time and effort to locating the positions and movements of heavenly bodies. To measure angular distances between stars, they constructed sights on a wooden or metal rod, much like those on a gun barrel, and mounted the rod on a wooden or metal circular disk which was divided into 360 equal parts. These parts were called degrees, although they are not the same degrees as those used on a thermometer (see page 29).[1] This instrument, which is called an *astrolabe,* made it possible to locate a star and record its position in the sky.

INSTRUMENTS FOR ASTRONOMY

The first telescope. A man named Lippershey, who lived in Holland, is usually believed to have invented the first telescope about 1608. It consisted of a tube in which special-shaped pieces of glass, with one or both sides curved, called *lenses,* were so placed that distant objects could be seen more clearly.

Galileo, an Italian, was a curious person, who wanted to determine the accuracy of some of the ideas about the universe commonly believed at that time. Therefore when he heard about Lippershey's invention, he built his own simple telescope. With it he discovered stars that had never been seen before. He was convinced that the universe was larger than people believed it to be, and he made other observations disproving many of the popular ideas about the universe.

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[1] The same symbol (°) is used to indicate both kinds of degrees.

Kinds of light telescopes. You probably have looked at some distant object through field glasses. The object appeared much nearer than it did to the naked eye because the lenses in the field glasses magnified it. One kind of telescope, the *refracting telescope,* is constructed very much like field glasses. Its lenses are larger and gather more light; they also make distant objects appear to be much closer. The largest refracting telescope, with a lens 40 inches in diameter, makes objects such as the moon appear 2,000 times as large as they look to the unaided eye.

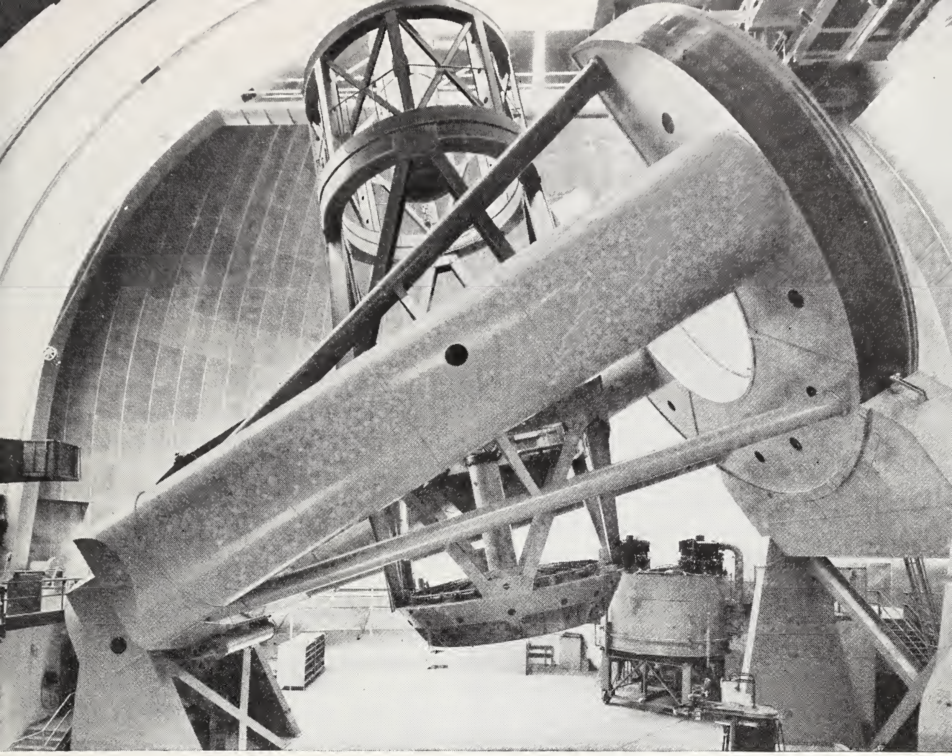
It has been found impractical to make refracting telescopes with a lens larger than 40 inches in diameter. For greater light-gathering ability, therefore, the *reflecting telescope* is used. Instead of having lenses through which light passes, this telescope has large mirrors reflecting the light from distant stars into an eyepiece from which they can be observed or into a camera. The largest light telescopes in use today are reflecting telescopes.

The largest light telescope. The largest light telescope in the world is the 200-inch reflector on Mt. Palomar in southern California. It weighs over 500 tons, and it took fifteen years to construct. In the picture on page 101, you can see the size of this instrument. With the 200-inch telescope, eight times as much space in the universe can be explored as with any other telescope. It can collect 640,000 times as much light as the human eye. Its light-gathering power is four times that of the next largest telescope.

Instruments used with the light telescope. Many important discoveries could not have been made without cameras attached to telescopes. In fact, Dr. Ira Bowen, who is in charge of the 200-inch Hale telescope, has said that the telescope should really be called a 200-inch camera. Because a photographic plate or film in the camera may be left exposed for minutes or even hours to the very faint light coming into the telescope from a distant star, stars which cannot be seen by the human eye show on the photograph. Photographs are permanent records of stars. They are more accurate than drawings and written descriptions.

The *spectroscope* is another valuable instrument for exploring heavenly bodies. The spectroscope contains a triangular-shaped piece of thick glass called a *prism.* When sunlight which has passed through a prism falls on white paper, the colors of the rainbow are seen on the paper. This rainbow effect is called the *spectrum* of sunlight. Every star has its own spectrum. By studying the spectrum of the star's light, scientists can determine by the *if—then* method the chemical composition of the star, the speed at which the star is moving toward or away from the earth, and its temperature.

The *coronagraph* is one of the most valuable instruments for studying the sun. With it the astronomer can photograph the outer fringes of the sun.



Palomar-Mt. Wilson Observatory

The 200-inch Hale Telescope at Palomar Observatory. A man sitting at a control desk can dial any star position. A pushbutton makes the telescope automatically move into position and follow the star as it moves across the sky.

Other instruments measure the exact positions of stars, the diameters of stars, and the amount of light they give off.

Radio telescopes. Strange hissing radio noises which seemed to come from nowhere here on the earth caused certain astronomers to wonder if they could be produced by stars in outer space. Radio telescopes similar to the one shown on page 141 were built and used for radio observation of the suspected stars. About 200 stars, including our sun, were discovered to be giving off radio waves. The discovery of the first radio star in 1948 opened up an entirely new way of studying certain stars.

One of the world's largest radio telescopes is located in Cambridge, England. It is a series of radio antennas 300 feet long and 40 feet wide. Astronomers believe that with this telescope they will locate up to 1,000 or more radio stars. One of its advantages is that the earth's atmosphere does not affect radio waves. It can also be used during daylight as well as at night.

The radio telescope will lead to

many new discoveries. Already it has located stars that had never been seen with light telescopes. Although the surface temperature of the sun is 6000° C, its upper atmosphere has been found by the radio telescope to have a million-degree temperature. Thus new instruments add to man's knowledge about the universe.

Mathematics aids astronomy. Though a number of instruments are used in studying heavenly bodies, the distances, positions, movements, and other characteristics of these bodies cannot be measured directly as you would measure the distance between your home and the school. Nor can you measure their sizes as you can measure the size of a basketball. The measurements must be made indirectly. For this purpose astronomers must make mathematical calculations based on their observations with instruments. When you study *geometry* and *trigonometry* you will understand better how mathematics has been used by astronomers.

The astronomer's laboratory. The laboratories in which astronomers work are called *observatories.* Most observatories are equipped with many of the other useful instruments in addition to several types of telescopes. To construct and equip these observatories costs millions of dollars, and thousands of dollars annually are spent to operate them. Generally the astronomers of each observatory specialize in a certain kind of study.

Space travel. Man's desire to see what it is like beyond the atmosphere of the earth has led to a great deal of speculation about space travel. Based upon knowledge which scientists now have, some believe that man will one day travel into space. If it ever becomes possible for astronomers to view the universe unhindered by our atmosphere, much more will be added to what we now know about the universe.

SUMMARY

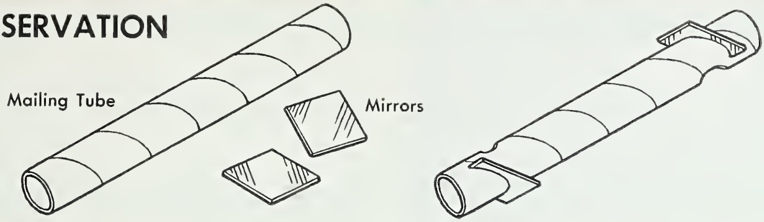
Discoveries about the universe have resulted from man's curiosity about his surroundings. Early man collected facts about the universe from his limited observation of the sun, moon, stars, and earth. He lacked the necessary instruments for making accurate observations. As a result, many of his generalizations about the nature of the sun, moon, stars, and earth are not accepted today.

By using mirrors and lenses, man has developed telescopes that will collect hundreds of thousands of times more light than the human eye. A number of instruments have been developed for use with the light telescope and have enabled man to improve the accuracy of his observations. By using radio waves, man has discovered a new way of learning more about the universe.

OBSERVATION

Exercises called *observations* will be provided at the end of some of the problems in this book. They have been planned to help you obtain a better understanding of the facts and generalizations included in the problem. They will also give you practice in making generalizations based upon what you observe.

OBSERVATION



What to observe. How light is controlled in a reflecting telescope.

How to observe it. As shown in the diagram of the reflecting telescope on page 99, mirrors are used to pick up the light from a distant star and to direct it through the eye piece. You can observe this in the following manner. Obtain a mailing tube about 2 inches in diameter and 2 feet long. About 3 or 4 inches from each end of the tube cut slits at angles of exactly 45 degrees, as shown. Insert a pocket mirror into each slit, the top one mirror side down, the bottom one with mirror side up. Cut a round hole about 1½ inches in diameter directly opposite one mirror, and a smaller hole to look through opposite the other mirror. Use the tube to observe a lighted candle and other objects.

Interpretation of your observation. Explain how the light enters the tube and is controlled within the tube so that you can see the image by looking in at the lower end of the tube.

OBSERVATION

What to observe. The magnifying power of a lens.

How to observe it. Hold a hand lens in focus over ruled paper. Measure the width of one line on the paper and compare with its width as observed through the hand lens. Have several members of the class repeat the observation and record their results.

Interpretation of your observation. Answer the following question in one complete sentence: How much wider was the magnified image of the line?

TEST YOURSELF

Select the ending which best completes each statement and write its letter in the proper place on your answer sheet.

1. Ancient man made inaccurate generalizations about the universe because (a) he was not intelligent; (b) he did not know how to reason; (c) he was limited in the number and kind of observations he could make; (d) he was not interested in the stars above him.
2. A telescope which depends entirely upon lenses for its operation is called (a) a reflecting telescope; (b) a refracting telescope; (c) a condensing telescope; (d) an astronomical telescope.
3. An instrument which spreads out sunlight into the colors of the rainbow is called (a) a spectroscope; (b) a coronagraph; (c) an astrolabe; (d) a sextant.
4. The largest light telescopes in use are (a) reflecting telescopes; (b) refracting telescopes; (c) radio telescopes; (d) camera telescopes.
5. One of the newest ways of studying the universe is by (a) astrolabe; (b) reflecting telescope; (c) radio telescope; (d) spectroscope.

PROBLEM 2. What has been learned about the universe?

A roll call of the universe. Because we live here, the earth is very important to us. In comparison with other bodies in the universe, however, the earth is small and unimportant. It is only one member of a large group of bodies called the *solar system*. At the center of the solar system is the sun. Nine bodies called planets, one of which is the earth, revolve around the sun. The moon and the *comets, meteors,* and *asteroids* are also members of the solar system.

Outside the solar system are many other suns, or stars. In fact, the sun is only a medium-sized star among millions of others that make up our *Galaxy*. Astronomers believe that the universe, in turn, is made up of millions of galaxies. Between the millions and millions of stars and between the millions of galaxies there is vast space. Most of the universe is space.

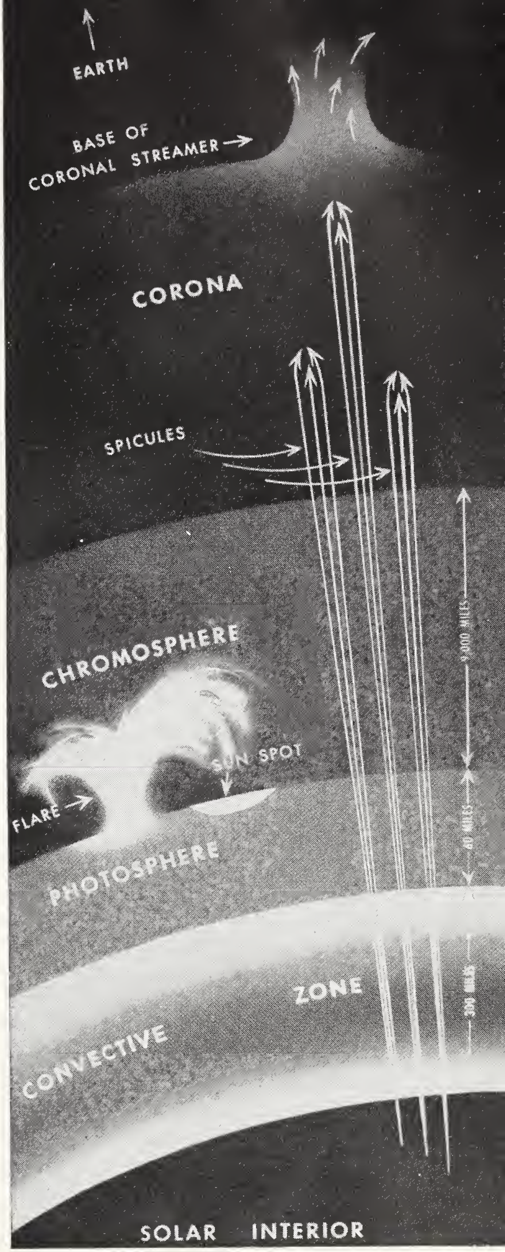
THE SUN

Looked at through a piece of smoked glass, the sun appears to be about the same size as the moon. Actually it is much larger. In fact, a dozen moons dropped into the sun at one time would make a spot that would hardly be visible from the earth. The diameter of the sun is about 864,000 miles, but because the sun is about 93,000,000 miles from the earth, it appears much smaller.

All the bodies in the universe are attracted, or pulled, toward one another by a force called *gravity*. Everything on the earth, including the atmosphere, is held where it is by the pull of gravity. Sir Isaac Newton, a great English scientist, discovered that the pull of one body upon another increases with the amount of matter in the two bodies and decreases as the bodies are farther apart. Because the sun contains much more matter, its gravity is about thirty times as great as that of the earth.

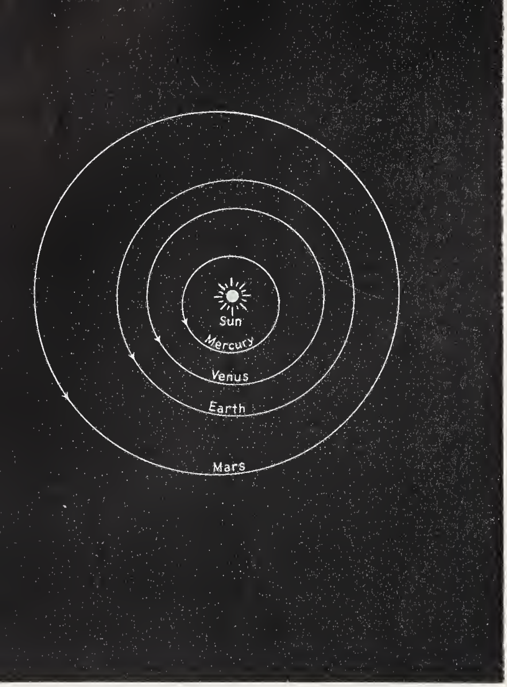
The sun is an extremely hot, gaseous body. No furnaces on the earth can produce the high temperatures that exist in the sun. Its surface temperature is about 6000° C but the temperature inside the sun is approximately 22,000,000° C. About 60 chemical elements, including iron, have been identified in the sun. Because of the extremely high temperatures, these elements are in gaseous form.

The sun's atmosphere. As shown on the right, scientists who study the sun have divided its atmosphere into a number of layers. The *photosphere* is the layer which we ordinarily see. It is separated from the interior by a *convective zone. Solar flares* appear from time to time in the region of *sun spots.* The *corona,* a pearly white layer of gases, can be observed with the coronagraph or at the time of a solar eclipse. It is believed by some scientists that long streamers of invisible gases extend millions of miles out from the corona. They further believe that the corona is constantly resupplied from the interior of the sun by long jets of heated material called *spicules.* When



Radio Corporation of America

Action in the sun's atmosphere.



Relative distances between orbits of the four planets nearest the sun. Orbits of the other planets are too far from the sun to be shown here. The orbit of Pluto would be over 28 inches from the sun.

a number of spicules are clustered in one region, a coronal streamer is formed.

PLANETS

Each planet travels around the sun in a curved path called an *orbit*. The swinging motion of the planet as it moves around the sun tends to throw it into outer space because of centrifugal force (see page 56). At the same time, the planet is pulled toward the sun by the force of gravity. Since these two forces for each planet are equal, the planet moves around the sun in the same orbit year after year.

The movement of the planets around the sun is called *revolution,* and the time it takes a planet to complete its orbit is its *period of revolution.* The period of revolution for the earth is used as the length of a year. As the table on page 107 shows, each planet has a different period of revolution. The greater the distance from the sun, the longer the period of revolution.

As each planet revolves around the sun, it also turns on its *axis.* The axis is an imaginary line passing through the center of the planet. The time required for each planet to turn on its axis is shown on page 107. This movement of a planet is called *rotation.* The time it takes the earth to make one rotation is used as the length of our day (24 hours).

Most of the planets have one or more smaller bodies, called *satellites,* closely associated with them. The moon is the earth's satellite.

Planets are not light-producing bodies like the sun. The light which comes to us from the planets is reflected sunlight.

Mercury. Mercury is the smallest planet, having a diameter about one third that of the earth. It is the planet nearest the sun. Its period of rotation and revolution are the same, 88 days. Therefore, during the time that Mercury makes one trip around the sun, it has made one complete turn on its axis. For this reason, Mercury always has the same side toward the sun. It is always day on the side facing the sun. The temperature of this side is generally about seven times greater than the warmest days on the earth. The

COMPARISON OF PLANETS OF THE SOLAR SYSTEM

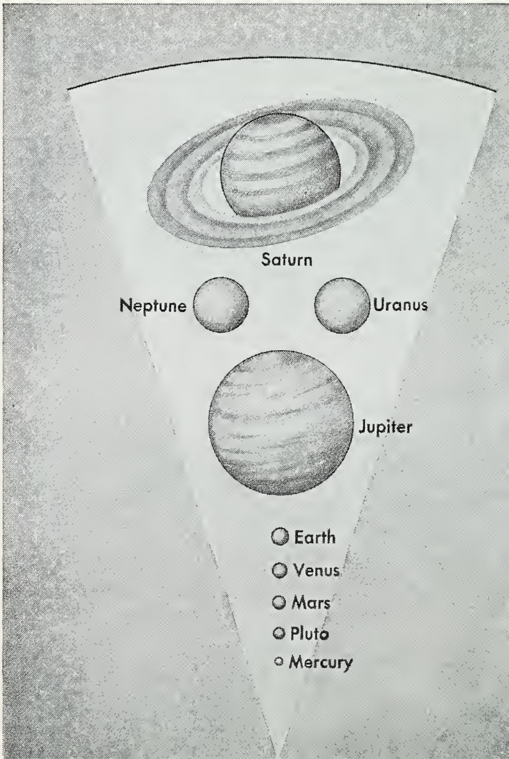
PLANET	DIAMETER IN MILES	AVERAGE DISTANCE FROM SUN IN MILLIONS OF MILES	NUMBER OF SATELLITES	ROTATION-LENGTH OF DAY IN EARTH TIME	REVOLUTION-LENGTH OF YEAR IN EARTH TIME
Mercury	3,100	36	0	88 days	88 days
Venus	7,700	67	0	uncertain	225 days
Earth	7,913	93	1	24 hours	365¼ days
Mars	4,216	142	2	24½ hours	687 days
Jupiter	86,700	483	12	10 hours	12 years
Saturn	71,500	886	9	10¼ hours	29½ years
Uranus	32,000	1,780	5	11 hours	84 years
Neptune	28,000	2,800	2	16 hours	165 years
Pluto	about size of earth	3,700	none known	uncertain	248 years

opposite side receives no direct sunlight and is therefore cold. Mercury has no atmosphere. Because of the extreme temperatures and the lack of oxygen, it would not be possible for any living thing we know to exist on that planet.

Venus. Although Venus is the planet nearest the earth, we do not know very much about it because a dense cloud surrounds it. Astronomers have not been able to find an opening in this cloud through which they can see the surface of our next-door neighbor. Consequently the rate at which Venus rotates on its axis has never been measured accurately. Although it has been established that there is carbon dioxide in its dense atmosphere, it is believed there is not enough oxygen or water vapor on Venus to support life. The heavy cloud around Venus serves as an excellent reflector of light from the sun. Thus it is the brightest of all planets.

The earth. The diameter of the earth is about 7,900 miles. As will be noted,

Planets are extremely small compared to the sun. Their relative sizes are represented by the smaller circles in the "pie-shaped" section of a larger circle representing the sun.



Yerkes Observatory

Saturn as photographed through a telescope shows the dramatic rings for which it is known.

page 106, the earth's orbit lies between the orbits of Venus and Mars. Traveling at a speed of more than 1,000 miles a minute, the earth completes its long journey of 580,000,000 miles around the sun in 365¼ days. The earth rotates on its axis once every 23 hours and 56 minutes. During this period it also moves along more than 1,500,000 miles on its orbit. The axis is not vertical, but is tilted to one side, as shown on page 122. This tilting of the earth's axis accounts for change of seasons, which will be explained in the next chapter.

Mars. Next to Venus, Mars is our closest planetary neighbor. Its diameter is a little more than half that of the earth. Mars' atmosphere is so thin that an earth man could not live there without a pressurized suit. Its axis tilts much as the earth's does, and it has seasons. During the day its temperature rises to about 80° F. At night, however, the temperature drops suddenly to 95° below zero F. It is believed that there is some water on Mars and a small amount of oxygen in its atmosphere.

Through the telescope, astronomers have seen large reddish deserts, blue cloud formations, and white polar caps on Mars. During the spring the polar caps appear to melt and, in part, are replaced by blue-green areas. Later in the season these areas turn brown. Some astronomers have seen delicate lines forming a regular pattern over the surface of Mars, although others with just as good telescopes have been unable to see them. Because of these observations there has been a good deal of speculation about the possibility of life on Mars. If there is, it would have to be pretty rugged.

Asteroids. Between Mars and Jupiter there is a large group of little planets ranging in size from 480 miles in diameter to mere chunks of rock. They are called *asteroids* or *planetoids*. More than 1,500 of them have been discovered. One of these asteroids, Eros, has come within 14,000,000 miles of the earth. It is thought that the asteroids are pieces of larger planets which were broken up by some unknown force long ago.

Jupiter. Jupiter is so huge that if it were hollow, all the other planets could be put inside of it with room to spare. It is so far from the sun that sunlight which reaches it is only about one thirteenth as strong as that which comes to the earth. The atmosphere surrounding Jupiter is so thick that its surface cannot be observed. With a special instrument astronomers found that the surface temperature of Jupiter is about 200° below zero Fahrenheit. Jupiter has twelve satellites, or moons, as they are called.

Saturn. Through the telescope, Saturn presents one of the most spectacular sights in the heavens. It is surrounded by a beautiful system of rings which are really a multitude of fine particles revolving about it. Half the light we receive from Saturn is reflected to us from these rings. Like Jupiter, Saturn has a dense atmosphere. Because of its distance from the sun, the sun's light is only about 1/100 as strong as it is on the earth and the temperature is very low. This is one of the reasons why life as we know it could not exist on Saturn.

Uranus and Neptune. Three planets beyond Saturn's orbit have been discovered since 1780. Uranus was discovered by Sir William Herschel in 1781. Because it appeared as a disk through the telescope, it was identified as a planet. Through the telescope, planets always appear as disks, whereas stars are always points of light. The second planet, Neptune, was discovered in 1846. Before it was actually discovered with a telescope, both its presence and position had been predicted because of the effects of its gravity upon Uranus. Neptune and Uranus are alike in several ways. As will be noted on page 107, they are about the same size. Both have heavy cloud-covered surfaces. Uranus receives only 1/400 as much sunlight as the earth, and Neptune only 1/900 as much.

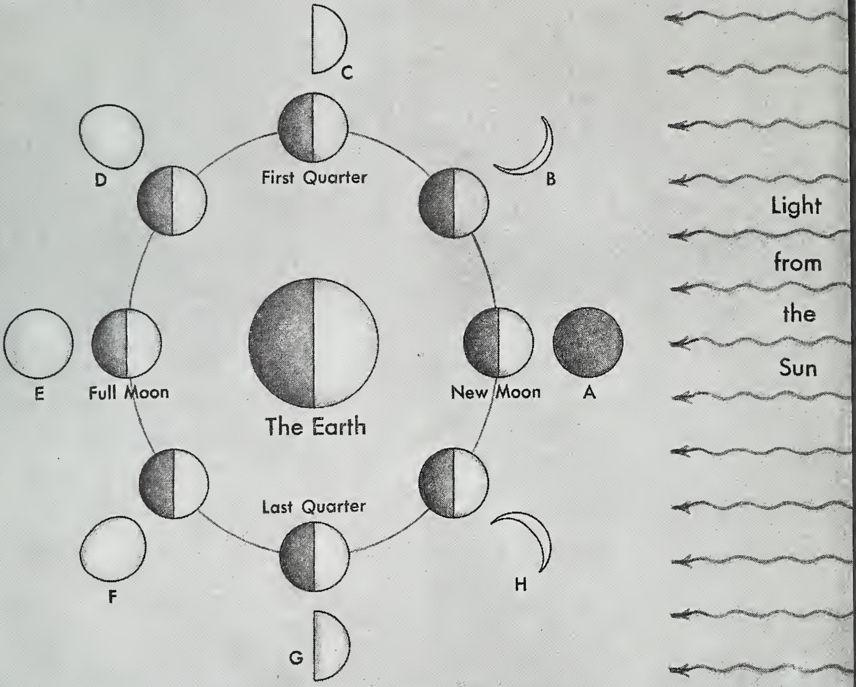
Pluto. The existence of Pluto, the third planet beyond Saturn, had also been predicted mathematically before it was discovered in 1930 during a thorough photographic search. As yet very little is known about it. Its extreme distance from the sun would make it a very cold body. Its surface temperature is about 350° below zero Fahrenheit. It is very doubtful that any sort of life exists on Uranus, Neptune, or Pluto.

THE MOON

The moon is not a great deal smaller than the earth. It has a diameter of 2,100 miles. The earth and the moon both revolve around the sun. Their orbits are about 240,000 miles apart on the average. The movements of each are affected by the gravity of the other. At one time the moon is ahead of the earth and at another it is behind. This makes it appear that the moon revolves around the earth. The moon appears to revolve in an orbit around the earth in 27⅓ days, if it is timed from the moment that it passes a certain star until it once again passes that same star. While the moon goes from

The moon as photographed through a telescope. Note the craters that appear like spotted depressions on the surface.

Yerkes Observatory, Williams Bay, Wisc.



Phases of the moon. As the moon moves around the earth one-half of it is always lighted by the sun, and we see the lighted half during full moon. At other times we see the moon as shown in positions A, B, C, D, F, G, and H.

one side of the earth to another and back again, the earth has moved almost 1/12 of a revolution around the sun. If, therefore, the period of the moon's revolution is counted from one full moon to the next (see above), it amounts to 29½ days. Since the moon makes one turn on its axis while appearing to revolve around the earth in the same direction, we always see the same side of the moon.

If you were to observe the moon through a telescope, you would see its surface as a vast expanse of plains broken by jagged mountain ranges. There are thousands of depressions on the surface, called *craters*. Some of the craters are less than a mile in diameter; others are as large as 50 miles.

The moon has neither atmosphere nor water. Without an atmosphere, the side facing the sun becomes extremely hot, whereas the other side is cold. Since there is no water on the moon, its surface has not been eroded like that of the earth.

Phases of the moon. The moon has no light of its own; it reflects the light of the sun to the earth. As it makes its monthly journey around the earth, it seems to change its shape, but does not really do so. The drawing above will help you to understand why it appears to do so from the earth. The different shapes which we see are called the *phases* of the moon.

COMETS AND METEORS

Comets. Ancient people feared the comets because of their unusual appearance. Once the nature of comets was understood, fewer people were afraid of them. In general, comets have both a head and a tail, but some comets have no tail. The central part of the head is probably small solid particles, while the outer portion is made up of extremely thin gases. The tail is very light gaseous material and does not appear until the comet approaches the sun. Rather than always trailing behind the head of the comet, the tail extends away from the sun. Thus the comet's tail may extend from its side or may go ahead of the comet. Some comets have a diameter greater than that of the sun, whereas others may be as small as the earth. If the earth should pass through a comet tail, we would only see a display of "falling stars." But if the head of a comet should hit the earth, it would be more serious.

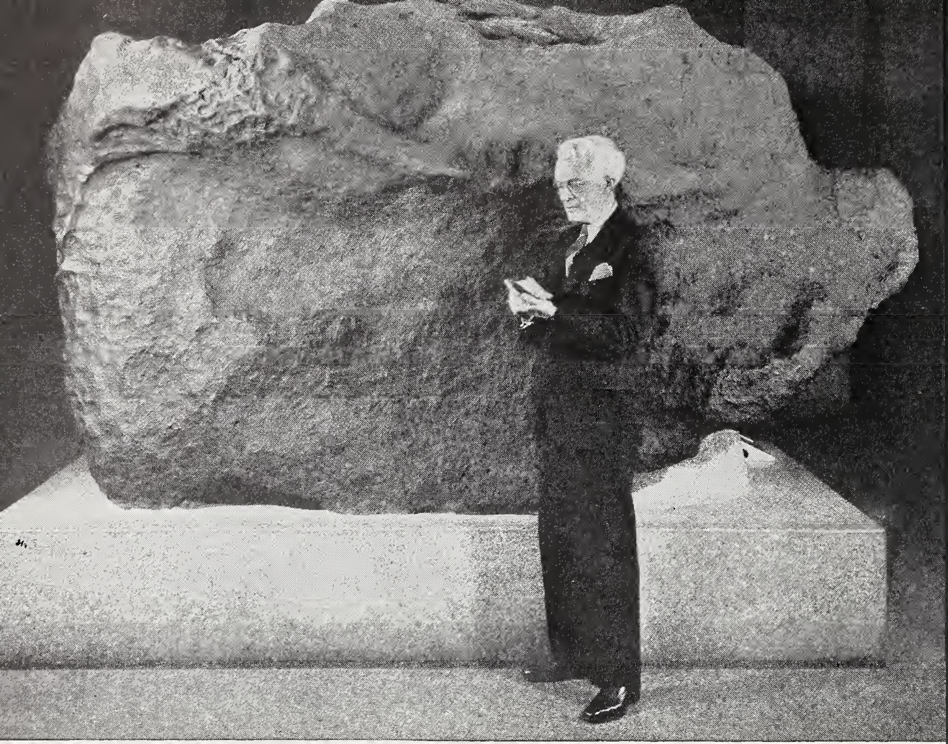
Comets are considered members of the solar system because they move around the sun. The orbits of most comets extend beyond the orbit of Pluto. Some are so far from the sun that their periods of revolution have not been determined. Because comets are visible only when they are near the sun, it is believed that not more than 10 per cent of the existing comets can be seen from the earth. Halley's comet requires about 76 years to complete its trip around the sun; another comet has been discovered that completes its orbit in a little more than three years.

Meteors and meteorites. Within the solar system there are many chunks of rock and metal that usually move through space in clusters or swarms like the material in comets. They seem to come from comets that have broken up, and they travel at very great speeds. When they enter the atmosphere of the earth, they rub against the gases there, and this rubbing, called *friction,* causes them to become very hot. Most of the chunks are completely burned and thus never reach the earth. We see them as "shooting stars." These pieces are called *meteors.* It is estimated that more than 10,000,000 meteors hit the earth's atmosphere every day.

The larger chunks that are not completely burned in the atmosphere fall to the earth. They are called *meteorites.* Some of them consist mostly

Morehouse's Comet as photographed November 16, 1908. Although it was barely visible to the naked eye, photographs taken of it through the telescope on different nights made it possible to observe violent changes that took place in the tail of the comet.

Yerkes Observatory, Williams Bay, Wisc.



American Museum of Natural History

The Ahnighito Meteorite brought from Greenland by Admiral Peary in 1897 and now located in the Hayden Planetarium, New York City. This is an iron meteorite weighing 36.5 tons; it is believed to be the second largest meteorite yet found.

of iron and nickel; others are stone. A meteorite weighing many hundreds of tons is believed to have fallen in Arizona several thousand years ago. Some believe that it was the head of a comet. The crater it formed is almost a mile across the rim and is about 550 feet deep. Because many meteorites explode and others fall in places where no one lives, it is very difficult to determine how many meteorites hit the earth each year. Estimates range from 70 to 1,100 a year. The likelihood of being hit by a meteorite is very small.

THE STARS

Distances beyond the solar system. Distances from the earth to stars beyond the solar system are so vast that they must be measured in a unit much larger than the mile. These distances in the universe are measured in *light-years*. A light-year is the distance that light travels in one year. Light travels approximately 186,000 miles a second, or about six million million miles a year. The nearest known star, other than the sun, is four light-years from the earth.

Star names. Have you ever tried to count the stars? You probably soon gave up, for the sky seems filled with stars far too numerous to count. But without field glasses or a telescope, actually only about 3,000 stars can be seen at one time from one place on the earth. Many stars have been named by groups, or *constellations.* It was imagined that different groups of stars resembled in outline some familiar object. Constellations were therefore named after the object they seemed to resemble. Eighty-eight such constellations have been named, two of which are Orion, the hunter, and Scorpius, the scorpion.

Astronomers name individual stars according to the constellation in which they are located and according to their brightness in that constellation. For example, the brightest star in the constellation Lyra is commonly called *Vega,* but astronomers also call this star Alpha Lyrae. Alpha, the first letter of the Greek alphabet, is used for the brightest star. Alpha Lyrae therefore means that Vega is the brightest star in the constellation Lyra. The other letters of the Greek alphabet are used in order in the names of the other stars in the constellation to indicate the order of their brightness. But not all stars can be named in this way, since there are only 24 letters in the Greek alphabet. Fainter stars are indicated by their position.

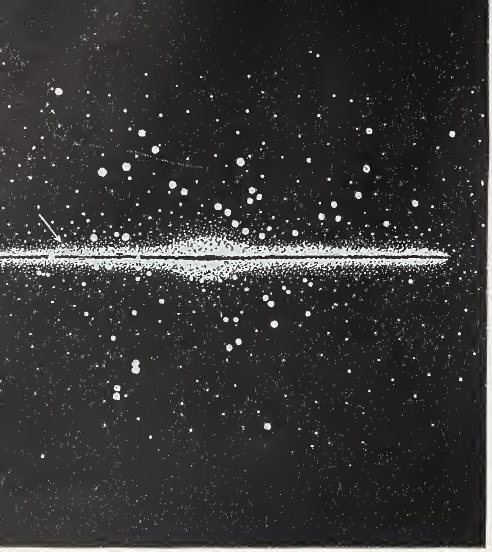
Sizes of stars. Regardless of the power of the telescope used, no star other than the sun appears to be more than a point of light in the sky. It is extremely difficult, therefore, to measure the size of any star accurately. But astronomers have developed an indirect method of measuring the size of the stars by studying the light they send to the earth.

Antares, Alpha Herculis, Omicron Ceti, and Betelgeuse have the largest known diameters. Antares has a diameter of 390,000,000 miles. This is four times the distance from the earth to the sun and more than twice the diameter of the earth's orbit (186,000,000 miles). Antares occupies 90,000,000 times as much space as the sun, but it weighs only about 30 times as much as the sun.

The smallest star known, Van Maanen's star, is about the size of the earth. If the sun were hollow, more than a million such tiny stars could be packed into it with space to spare. Though Van Maanen's star is about one millionth as large as the sun, it is about one fifth as heavy as the sun. The substance making up this tiny star is 66,000 times as heavy as the materials making up the earth. A piece of this heavy star substance about the size of this book would weigh almost 600 tons.

Colors of stars. The color of a star is a clue to its surface temperature. Bluish white stars are the hottest. Their surface temperature is approximately 20,000° C. White stars have a temperature of approximately 10,000° C; yellowish white, 7000° C; yellow, 6000° C; and orange, 4000° C. Red stars are the coolest, with a surface temperature of approximately 3000° C.

Nebulae. Within our own vast system of stars are large clouds of gases that glow brilliantly from the light of stars that lie within them or near them. They are called *nebulae* (*nebula,* for one) from the Latin for "clouds." These nebulae may have many forms. No two are alike.



A drawing of what our Galaxy might look like, showing the stars we can see, as well as the millions visible only through a telescope. The arrow indicates the approximate position of the solar system. It is 100,000 light-years across our Galaxy.

Galaxies. With high-powered telescopes astronomers have observed spiral-formed bodies outside our own star system. Astronomers believe that these bodies are made up of millions of stars. They are so far from the earth that the stars appear to be packed close together. The most distant ones that can be photographed with the most powerful telescopes are thought to be about one billion light-years from the earth.

Astronomers believe that our solar system, all the stars which we can see, together with many millions which can be seen only with a telescope, are arranged in a star system very much like these spiral-formed bodies. They call this star system our Galaxy (see drawing above).

The many millions of distant spirals are thought to be galaxies just like our own. If we could take a position within one of those distant galaxies and look upon our own, it would probably appear much like the galaxy shown on page 97.

Movement in the heavens. Stars are not "fixed"; they are moving through space at rapid rates. Because they are located at such great distances from the earth, their movement can hardly be detected. Accurate observation must be made with delicate instruments to detect movement of stars within the period of a human lifetime. Their movement is controlled by the same kinds of force that control the movement of the planets about the sun, (see page 106).

The entire community of stars which we call our Galaxy is also moving. Our Galaxy rotates around a central axis which is about 50,000 light-years from either edge. The solar system is located toward the edge of our Galaxy, approximately 30,000 light-years from the center. It takes nearly 225,000,000 years for the solar system to make one trip around the center axis of our Galaxy.

Astronomers believe that star communities making up other galaxies are rotating in much the same manner as our own Galaxy. They further believe that all galaxies in the universe are moving out from each other so that it would seem that the universe is expanding or getting bigger.

SUMMARY

It would be of little value for you to attempt to memorize all the facts about the universe presented in this problem. It is far more important that you understand some of the following generalizations about the universe:

1. The movement of bodies in the universe is regulated by gravitational and centrifugal forces and can be predicted.

2. The earth is a small, unimportant planet when compared with the many other bodies in the universe.

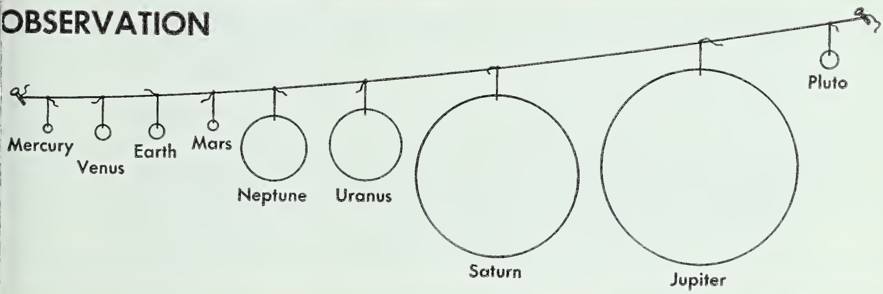
3. It is doubtful that conditions necessary for human life exist on any planet in the solar system other than the earth.

4. Since we live on one of the smaller, cooler bodies in the universe, it is difficult for us to imagine the large sizes, the great distances, and the high temperatures that exist in other places throughout the universe.

5. Our Galaxy is believed to be only one among the millions of galaxies in the universe.

6. Most of the universe is made up of space.

OBSERVATION

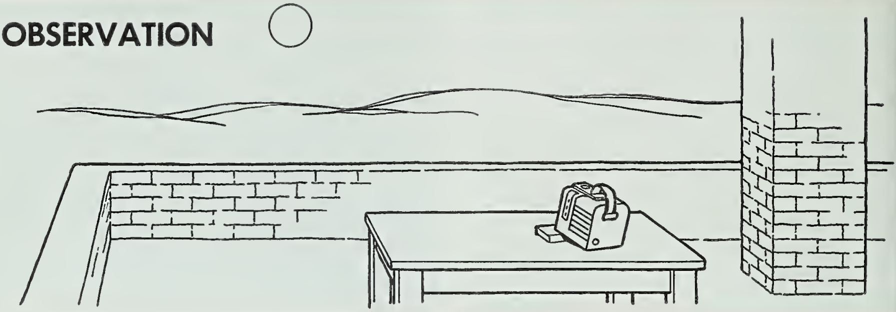


What to observe. The comparative sizes of planets and sun.

How to observe them. On the side wall of the classroom stretch a cord 22 feet long to represent the diameter of the sun. On a string stretched across the back of the room hang disks of paper of the following diameters, and label each to represent its respective planet: Mercury, 1 inch; Venus, 2⅝ inches; Earth, 2⅝ inches; Mars, 1⅜ inches; Neptune, 9⅜ inches; Uranus, 10⅝ inches; Saturn, 23⅝ inches; Jupiter, 28⅝ inches; Pluto, 2⅝ inches.

Interpretation of your observation. Write one complete sentence as an answer to each of the following questions: Why wasn't the sun represented by a paper disk in the above comparison? How does the earth compare in size with the other planets? How do the diameters of Saturn and Jupiter compare with the other planets? Excluding Saturn, how many of the other planets placed side by side would it take to equal the diameter of Jupiter?

OBSERVATION ○



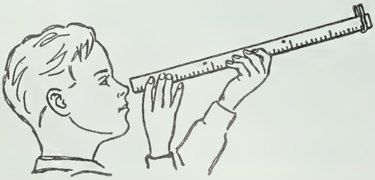
What to observe. The moon's path across the sky.

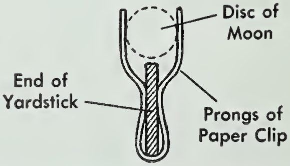
How to observe it. Astronomers use photographs to make many different kinds of records. You can record the path of the moon by taking a photograph with your camera. Even the simplest camera can be used.

On a night when the moon is clearly visible, set up your camera in as dark a place as possible, where you have a clear view of the sky. Through the finder, focus the camera on the moon. Make sure the camera is in a position away from the light and where it will not be moved. Open the shutter of the camera and leave it open for about two hours. After the film is developed and printed, observe the moon's path.

Interpretation of your observation. Why was it necessary to keep the camera from moving while you were taking the picture? Why was the shutter left open for two hours? What caused the path? When an astronomer wants to get a "still" picture of the moon through a telescope, what must he do?

EXPERIMENT ○





The question to be answered. Is the disk of the full moon actually larger when viewed near the horizon than when viewed higher in the sky? Before you begin this experiment, what do you think the answer is? Upon what evidence do you base your answer? If you do have an answer, then it might serve as your hypothesis and you could do the following experiment to test it.

What you need. A yard stick and a paper clip for each observer.

What to do. Make sighting bars by bending paper clips to fit yard sticks as shown in the diagram. When the full moon can be seen near the horizon, each observer should sight the moon through the two prongs of the paper clip, as shown in the diagram. The prongs should then be adjusted so that the moon's disk just fits between them. On several occasions during the evening when the moon is at different altitudes or distances up from the horizon, each observer should again use his sighting bar to observe the moon's disk. Make a record of each observation.

Some basic assumptions. 1. The position of the paper clip was not changed after the first observation.

2. Each observer made accurate observations.

3. This is the proper method for making such observations.

Your answer. Each observer should report his findings. From these findings, what conclusion regarding the above question can be made?

TEST YOURSELF

Read each of the following statements carefully. If a statement is true, write the word *true* in the proper place on your answer sheet. If the statement is false, write the word or words on your answer sheet which should be substituted for the ones in *italics* to make the statement true.

1. The sun is the center of the *universe.*
2. The earth is one of several bodies called *planets.*
3. There are nine known *comets* in the solar system.
4. The force of gravity of the sun is greater than that of the earth because the sun is *hotter* than the earth.
5. The star system of which the sun and its planets are a part is called our *Galaxy.*
6. A comet's tail, made of light gaseous material, always points *away from* the sun.

CHAPTER ACTIVITIES

REVIEW YOUR UNDERSTANDING

Write the answers to each item in the proper place on your answer sheet.

1. The names of a number of heavenly bodies are listed below, followed by a list of the different kinds of bodies

found in the universe. On your answer sheet after the number corresponding to each of the names, write the letter which indicates its kind.

HEAVENLY BODIES

1. The sun
2. The moon
3. Venus
4. Saturn
5. Eros
6. Halley's
7. Vega
8. Mercury
9. Capella
10. Neptune
11. Jupiter
12. Sirius
13. Antares
14. Betelgeuse
15. Pluto
16. The earth

KINDS OF BODIES

a. Planet
b. Star
c. Comet
d. Satellite
e. Asteroid
f. Meteorite

2. Below are listed two generalizations, each followed by several fact statements. On your answer sheet beside the number of the generalization, write the letter or letters of the facts which support it.

1. Astronomers can predict the movement of many heavenly bodies with great accuracy.
   a. The surface force of gravity of the sun is about thirty times that of the earth.
   b. The planets travel around the sun in regular orbits.
   c. Meteorites sometimes fall to the earth.
   d. Future dates upon which the moon will pass through its different phases are known.
   e. Halley's Comet will be nearest the earth again on April 29, 1986.
2. It is doubtful that conditions necessary for human life exist on any planet in the solar system other than the earth.
   a. Mercury has no atmosphere.
   b. Although Venus is the brightest of the planets, its atmosphere is believed to contain very little oxygen or water vapor.
   c. The length of day and night upon Mars is about the same as that on the earth.
   d. At night the temperature on Mars drops suddenly to 95° below zero F.
   e. The surface temperatures of Jupiter, Saturn, Uranus, Neptune, and Pluto are many degrees below zero Fahrenheit.
   f. Each of the planets rotates on its axis.

USE A TABLE OF FACTS

This is a test to determine how accurately you can read the table, Comparison of Planets of the Solar System, found on page 107. Some of the statements below are supported by information given in the table, whereas others are not. On your answer sheet, write a number for each of the statements. Place an **x** after the number of each statement supported by information given in the table.

1. Pluto has four moons.

2. The planets farthest from the sun have the longest years.

3. Mars is between the earth and the sun.

4. The diameter of Neptune is about 2,000 miles greater than that of Uranus.

5. Pluto has the longest year of any of the planets.

6. The planets farthest from the sun are the largest.

National Military Establishment

A naval navigation officer takes an observation of the sun with a sextant. He will use his observations in locating the position of his ship.

chapter 7 THE SUN, MOON, AND STARS

YOU may wonder if bodies such great distances from the earth as the sun, moon, and stars could have any effect upon you. This is not surprising because the problem of how the heavenly bodies affect human beings has concerned man for many ages. As you will recall, astrologers taught that planets, including the sun and moon, controlled events in the lives of people. Many of man's early ideas about the influence of the heavenly bodies upon him have been proved to be incorrect. Let us see how our lives are actually affected by the sun, moon, and stars.

PROBLEM 1. How are we affected by the sun?

ENERGY FROM THE SUN

From earliest times man has recognized that he is dependent upon the sun, although he has not always understood exactly how the sun affects him. It has been found that the sun is the source of all the energy on the earth. Yet the earth receives only $\frac{1}{200,000,000}$ of the energy given off by the sun. Energy from the sun reaches the earth in a form of *radiant energy,* which supplies the earth with light. It also raises the temperature of materials it strikes, thus increasing heat. Radiant energy from the sun also kills germs, thus aiding in protecting man from disease. Radiant energy in all its forms will be studied in detail in Unit 4.

The lighting and heating effect of the sun's rays are very important to us. Page 482 shows how the sun is responsible for our food, our fuels, our water power.

Using the sun's energy. Inventors have made numerous attempts to build engines to do work by using the heating effect of the sun's energy. None of them has been as effective as engines using coal and oil as the direct source of energy.

Effect of atmosphere upon energy from the sun. The atmosphere affects the amount of energy we receive from the sun. The air above the surface of the earth, together with the large amounts of water vapor, smoke, and other particles in it, reduces the amount of radiant energy the earth receives from the sun. Since atmospheric conditions vary greatly over the surface of the earth, the amount of radiant energy received at the earth's surface varies from place to place. At sea level on a very clear day the heating effect of the sun's rays is only about one half as great as it is beyond the atmosphere of the earth. From this it may appear that the atmosphere prevents us from receiving the greatest advantage from the sun's energy. In reality the atmosphere protects us from receiving too much energy. It also screens out harmful radiations. If there were no atmosphere on the earth, the heating effect of radiant energy from the sun would cause the surface of the earth to be so hot that we could not live here.

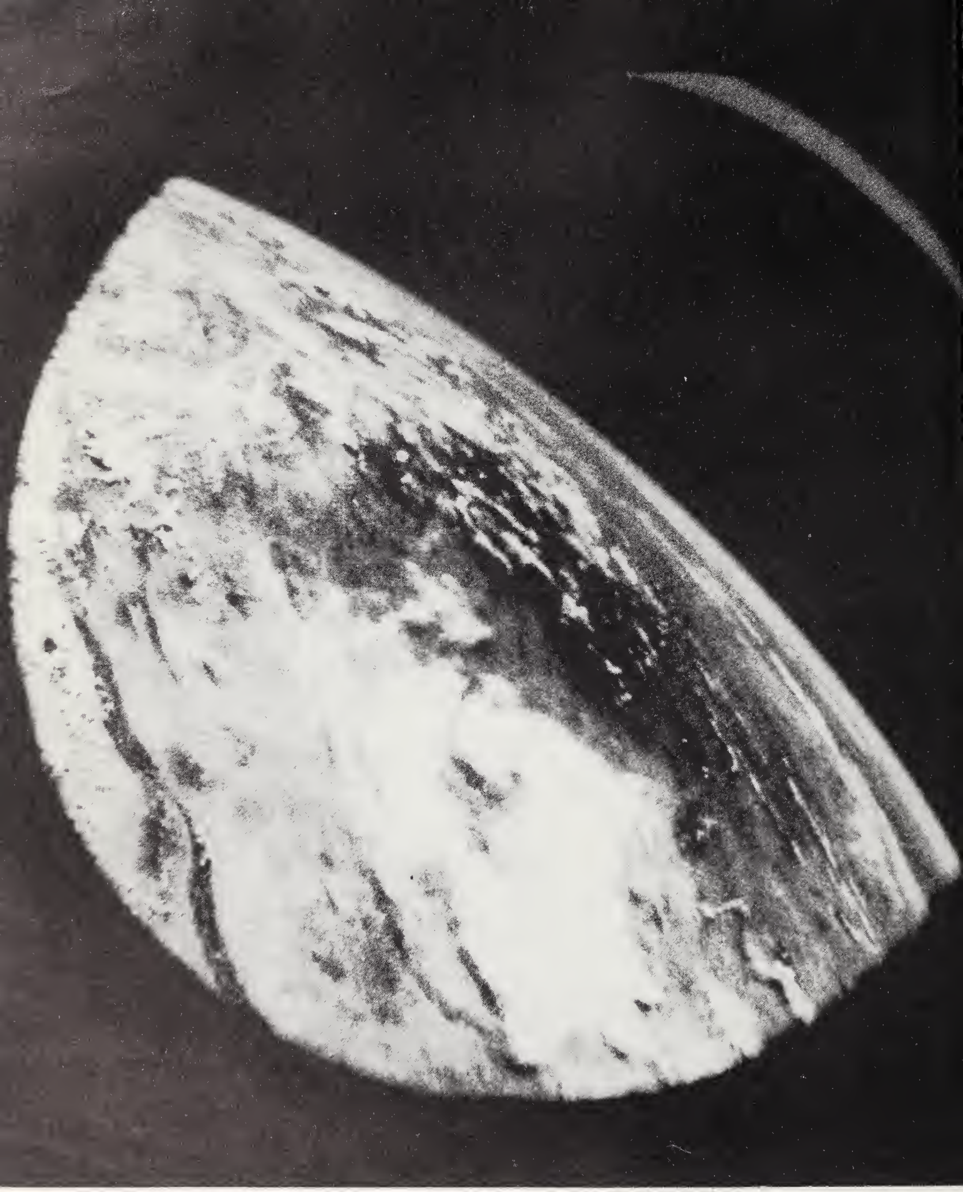
EFFECTS OF THE SUN

Blue sky and sunsets. The blue sky and the beautiful colors of sunsets result from the action of the atmosphere on the light passing through it. Sunlight includes light which can be made to produce several colors—violet, indigo, blue, green, yellow, orange, and red. As light passes through the atmosphere, the molecules of gases making up the air separate the light which causes blue from the light which causes the other colors. For this reason the sky appears blue. Beyond our atmosphere where there are very few molecules to separate the light, the sky is black.

The colors observed in a sunrise and a sunset are caused by particles in the atmosphere affecting light rays from the sun. When the sun is rising or setting, its rays pass through more of the atmosphere near the surface of the earth than they do at any other time. This part of the atmosphere contains

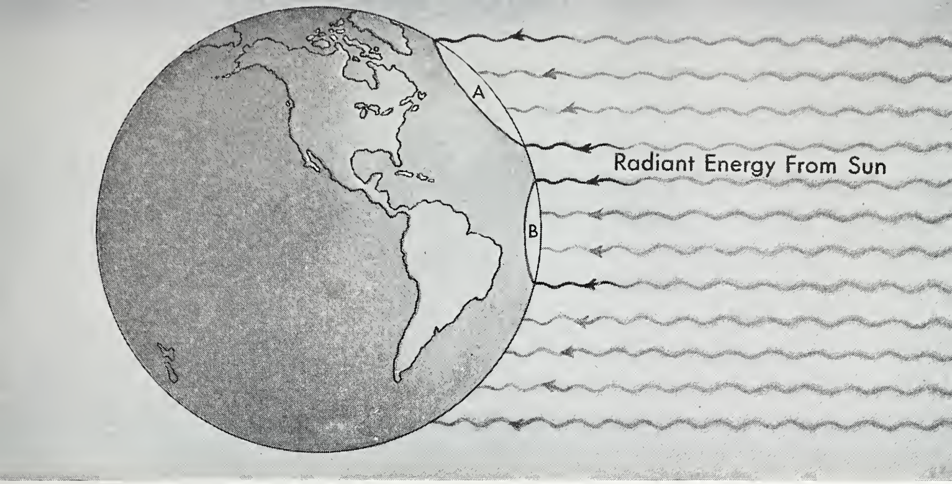
George Leavens for Colliers

Dr. Walter Orr Roberts, an astronomer at the Harvard High Altitude Observatory, looking at films of the sun taken with a coronagraph. This valuable instrument makes it possible to observe the corona of the sun which would otherwise be visible only during total eclipse.



U.S. Navy Photo

Cameras attached to rockets have made it possible for us to get our first view of the earth from high altitudes. This picture of the earth's surface was taken at an altitude of 100 miles and covers about 1700 miles horizontally. The dark streak at upper right is the Gulf of California; lower left area is the Rio Grande Valley.



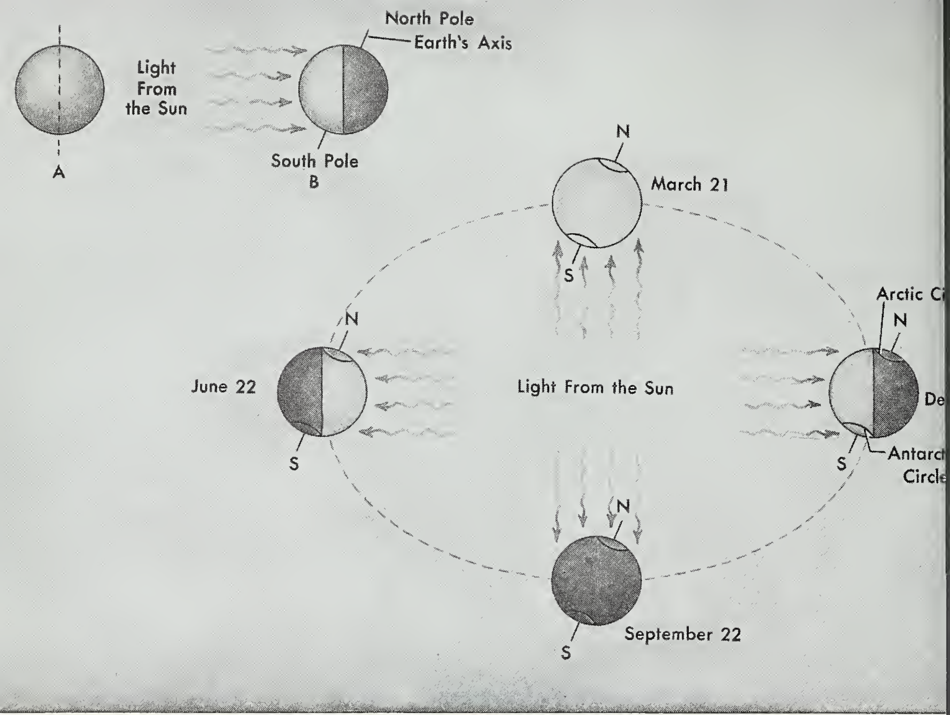
Rays of radiant energy striking the earth at A, above, are more slanted and cover a larger surface than rays striking the earth at B. Since the slanted rays at A cover a larger surface, they do not warm the earth as much as the rays at B.

many particles of dust, smoke, and other material. These particles are of such size that they separate the light that causes red, orange, and yellow from the rest of the sunlight. The result is the beautiful coloring of a sunrise or a sunset.

Radio interference. As you will learn in a later unit, there are layers of electrically charged gases surrounding the earth. These layers return certain radio waves back to the earth and make long-range high-frequency radio communication possible. At unpredictable times, however, something happens to them, causing radio fade-outs. Scientists who have been studying the sun with this problem in mind now think that radio fade-outs, in part at least, are caused by things that go on in the atmosphere of the sun (see page 105). It is believed that powerful radiations and electrically charged particles given off by solar flares, along with coronal streamers, are largely responsible for radio interference. By careful study of these solar activities, scientists hope to be able to predict the times when radio communication will be difficult.

Day and night. Day and night are caused by the rotation of the earth on its axis as it revolves around the sun. Since the earth is spherical, one half of its surface is lighted at any one time by the sun, as shown on page 122. You might expect that while the earth is making one complete turn on its axis, any one place on the earth would be lighted half the time and dark the other half. If this were true, every spot on the earth would have daylight for 12 hours and darkness for 12 hours; that is, day and night would be the same length. We know, however, that the length of day and night changes throughout the year and that on only two dates is it the same everywhere on the earth. What accounts for these differences?

If, while the earth rotated on its axis, it were in the position shown in A



If the earth's axis were in a vertical position, shown by the dotted line in A, length of day and night would be the same at all places on the earth. But the earth's axis is tilted 23½ degrees from the vertical, as shown in B, which accounts for changes in the length of day and night, as well as for changes in seasons.

above, the periods of light and darkness each day would be the same everywhere on the earth. Actually the earth is tilted at an angle as shown in B above. By comparing these two positions, you can see that the axis on which the earth rotates every 24 hours is not vertical but is tilted 23½ degrees. It remains tilted in the same position as the earth revolves around the sun. This tilting causes the length of day and night to change throughout the year and to be different for different parts of the earth as the earth follows its orbit around the sun (see above).

Note the position of the earth on December 22. On that date the length of daylight and darkness varies greatly at different places on the earth. While the earth is at this position in its orbit, the area within 23½ degrees of the North Pole is not touched by the sun's rays and is therefore dark for 24 hours each day. This area is bounded by an imaginary line called the *Arctic Circle.* During the same period the area within 23½ degrees of the South Pole, within the *Antarctic Circle,* is lighted by the sun's rays continuously. Places within this imaginary line therefore have 24 hours of daylight while those within the Arctic Circle are in darkness.

By March 21 the earth, in its journey around the sun, moves to the position shown on page 122. When the earth is in this position, the sun's rays strike it from the North Pole to the South Pole. Therefore on March 21 every place on the earth has 12 hours of daylight and 12 hours of darkness. On June 22 the earth reaches the position shown on page 122. Now the entire area within the Arctic Circle is lighted, while the area within the Antarctic Circle is in darkness. This is the opposite condition from that which existed on December 22. On September 22 the position of the earth is such that it is lighted by the sun as it is on March 21, with an equal number of hours of daylight and darkness. The steady movement of the earth around the sun produces the gradual changes during the year in length of day and night.

Seasons. The seasons also are explained by the fact that the axis on which the earth rotates every 24 hours remains tilted at the same angle while the earth follows its orbit around the sun every 365 days. As you can see, on December 22 the northern end of the earth's axis is tipped away from the sun. On this date at all points north of the *equator*[1] the sun appears to be farther south than at any other time during the year, and the rays of sunlight that reach these points are more slanted than at any other time.

When rays from the sun are slanted (see page 121), they cover a larger surface of the earth and consequently do not have as great a heating effect as they do when they strike the earth directly. The farther north a place is from the equator, the more slanted are the rays of the sun that strike it on December 22, the shorter the days, and the lower the temperature. For all places north of the equator, this is the winter season. December 22 is called the *winter solstice* (solstice means "sun standing"). The sun seems to stand still because it remains at the nearly northernmost point of its travel in the sky for several days in succession.

March 21 is called the *spring equinox* (equinox means "equal night") and ushers in the mild spring season; September 22 is called the *autumnal equinox* and introduces the fall season. June 22 is called the *summer solstice*. On that date, since the North Pole tips toward the sun, that part of the earth north of the equator, called the *Northern Hemisphere,* has its longest day and shortest night. The sun's rays that reach this hemisphere at that time are less slanted, and the days are warm. On the same date the rays that strike the part of the earth south of the equator, the *Southern Hemisphere,* are very slanted. The days are therefore cold. The Southern Hemisphere has its winter while the Northern Hemisphere is having summer and vice versa.

Time zones. The earth turns from west to east. The sun therefore appears to rise in the east. The farther east you live, the sooner you see the sun. As the earth continues to turn eastward throughout the day, the sun seems to move westward across the sky. The time of day when the sun is nearest the center of the sky in a particular region is called *noon*. We set our clocks and watches at 12 o'clock. If everywhere on the earth clocks were set to show 12 o'clock when the sun was nearest the center of the sky at any particular spot, there would be so many different times that it would be very confusing. To avoid such confusion and inconvenience, four standard time belts, or zones, have been established in the United States. All clocks within each zone show 12 o'clock at the same time regardless of the position of the sun, For example, Boston, Massachusetts, Buffalo, New York, and Detroit, Michigan, have the same clock reading, although the sun rises earlier in the more eastern city. As you will see below, the four standard time zones are named eastern, central, mountain, and Pacific. The difference in time between zones is one hour. When it is four in the eastern time zone, it is 3 A.M. in the central zone, 2 A.M. in the mountain zone, and 1 A.M. in the Pacific zone.

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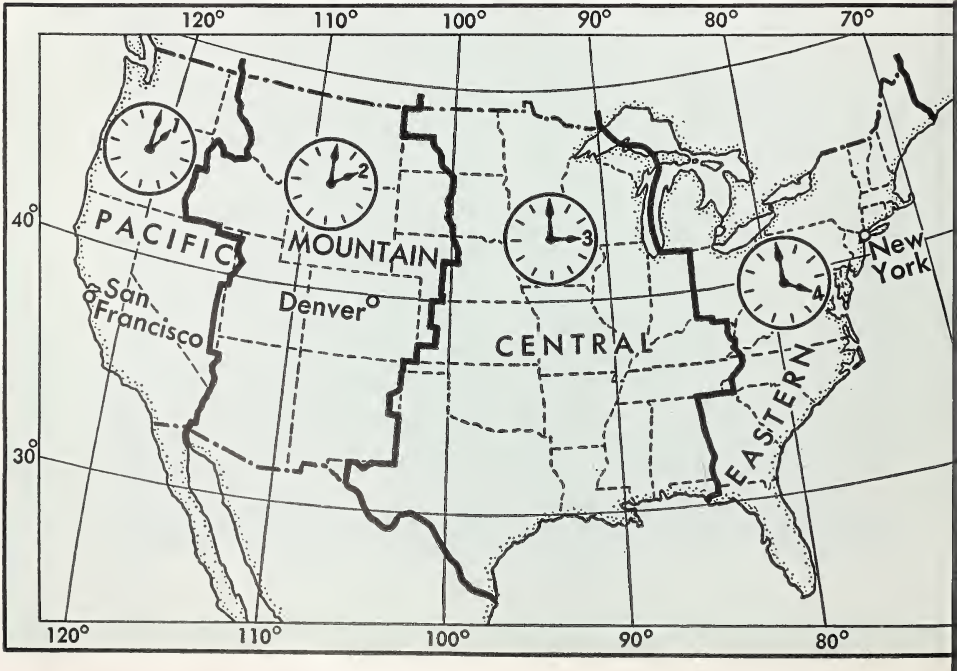
[1] The equator is an imaginary line around the earth halfway between the *North* and *South Poles*.

Daylight-saving Time. For about five months of the year, between May 1 and October 1, the sun rises between 4:30 and 6:00 A.M. and sets between 6 and 8 P.M. It has been found that during this period daylight can be used more effectively if our clocks are turned one hour ahead of standard time. The day then starts one hour earlier and it stays light one hour later by the clock. This is called Daylight-saving Time. Many cities and other communities in the United States observe Daylight-saving Time during the late spring and summer. It was used throughout the United States and in some other countries during World War II because it saved electricity.

The International Date Line. The earth has been divided, by international agreement, into 24 time zones, each zone corresponding to one hour of difference in sun time. If you were to start from Chicago, let us say, and travel westward around the earth, you would have to turn your watch back one hour as you entered each time zone. In other words, you would gain one hour by clock in each zone. By the

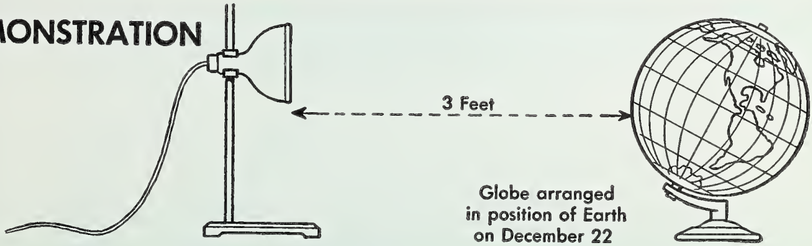


time you had completed your journey around the earth and had turned your watch back an hour for each time zone you entered, you would have gained 24 hours or one day. If you were to travel eastward around the world you would turn your watch ahead one hour as you entered each zone and would lose 24 hours. Obviously it would be impractical to change the calendar wherever we happened to be. In 1884 an international conference therefore established a definite line on the earth's surface along which the date is advanced or set back one day, depending upon the direction of travel. This is called the International Date Line. It is located in the Pacific Ocean and extends from the North Pole to the South Pole. It is not a straight line but zigzags to avoid crossing any important body of land. If you started traveling eastward, say, from Tokyo toward San Francisco on Tuesday, as you crossed the International Date Line you would set the date back one day to Monday. But if you started going westward from San Francisco toward Tokyo on Wednesday, you would set the date ahead one day to Thursday as you crossed the International Date Line. Losing a day at the International Date Line makes up for all the hours you gained by traveling westward around the world and setting your watch back one hour as you entered each of the 24 time zones. Likewise, gaining a day at the International Date Line as you travel eastward makes up for the hours you lost when you set your watch ahead one hour for each of the 24 time zones.

SUMMARY

The sun is the source of all the energy on the earth. The color effects of the sky, sunrises, and sunsets are made possible by sunlight. The length of day and night, the time of day, and the seasons of the year are determined by the relationship of the earth to the sun. Even though the sun is 93,000,000 miles from the earth, life on the earth would be impossible without it.

DEMONSTRATION



Generalizations to be demonstrated. 1. The rotation of the earth on its axis as it revolves around the sun accounts for day and night. 2. Changes in the length of day and night are caused by the tilting of the earth's axis.

What you need. Earth globe; clear glass "heat" lamp; ringstand and clamp; extension cord.

What to do. Arrange the heat lamp and globe as shown in the diagram, so that the rays from the lamp will shine directly upon the equator. Darken the room, turn on the lamp, and observe the lighted and darkened areas of the globe. Rotate the globe on its axis. Change the position of the globe so that its axis is tilted as the earth's would be on March 21, June 22, and September 22, and observe the light and dark areas as the globe is rotated.

What to observe. 1. How much of the globe is lighted?

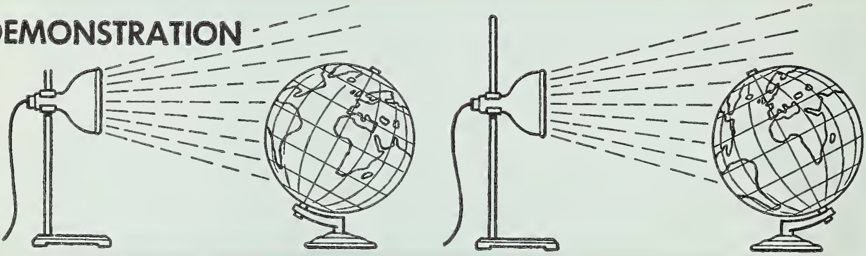
2. What part of the globe is lighted when it is in each position?

A basic assumption in this demonstration. The position of the globe with respect to the lamp is similar to the position of the earth with respect to the sun as it revolves around the sun.

What does it mean? How does the rotation of the earth produce day and night?

How does the tilting of the earth's axis account for the changes in length of day and night?

DEMONSTRATION



Generalization to be demonstrated. The tilting of the earth on its axis causes the sun's rays to be more slanted at one time than at another, thus producing the seasons.

What you need. Same materials used in previous demonstration.

What to do. Place the globe about two feet from the lamp and tilt the north pole away from the sun. Place your finger upon that part of the globe representing the position of the state in which you live. Note the amount of heat produced by the rays from the lamp. Now tilt the north pole of the axis toward the lamp and again note the heat produced by the lamp's rays.

What to observe. 1. In which position of the globe are the lamp's rays most slanted as they strike your finger?

2. In which position of the globe do you feel the most heat being produced by the rays from the lamp?

3. Which position of the globe represents winter and which summer in the United States?

Some basic assumptions in this demonstration. 1. The position of the globe with respect to the lamp is similar to the position of the earth with respect to the sun as it revolves around the sun.

2. The observed differences in temperature are accounted for primarily by the positions of the globe and not its distance from the lamp.

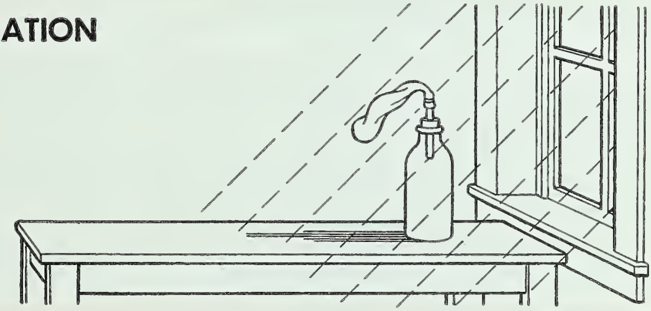
3. The rays from the lamp warm your finger in the same manner that the sun's rays warm the earth.

What does it mean? 1. How does the tilting of the earth's axis cause the sun's rays to slant more at one time than at another?

2. Why do slanted rays produce less heat than rays which fall directly upon a surface?

3. How does the tilting of the earth's axis as it revolves around the sun produce the seasons?

DEMONSTRATION



Generalization to be demonstrated. Radiant energy from the sun can cause work to be done.

What you need. Rubber balloon, rubber band, 6-inch glass tube, one-hole cork, bottle, and a candle or something else as a source of flame.

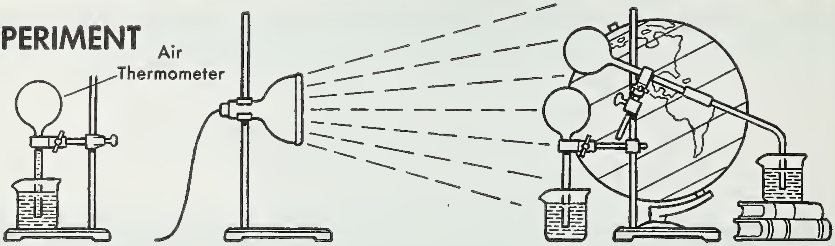
What to do. Stretch the balloon several times by blowing air into it. Blacken the bottle with carbon by holding it in a candle flame. Attach the balloon with the rubber band to one end of the glass tube and insert the other end of the tube through the hole into the cork. Fit cork tightly into the neck of the bottle. Place the set-up, as shown in the diagram, in the sun so that direct rays of sun fall upon the blackened bottle.

What to observe. What happens to the balloon? How long did it take?

A basic assumption in this demonstration. Work is being done when something is moved.

What does it mean? What was in the bottle? What caused the balloon to rise? Why was the bottle blackened? How does this prove that radiant energy from the sun can do work? Have you seen other illustrations of this?

EXPERIMENT



The statement to be tested. When rays from the sun are slanted, they do not have as great a heating effect as they do when they strike the earth directly.

What you need. Three air thermometer tubes, three beakers, red ink, clear glass "heat" lamp, ringstand and clamps, extension cord, earth globe, and a small box or several books.

What to do. Bend the stem on one air thermometer tube, as shown in the diagram. Set up the bent one and a second one in the water colored by the red ink, as shown in the diagram. Set up a third air thermometer the same way, but place it where rays from the lamp cannot reach it. This is your control. Arrange the air thermometers so that the level of the liquid is the same in all, and mark the level of the liquid on each. Turn on the lamp and allow it to shine on the bulbs of the two thermometers for ten minutes. Measure the distance the liquid has moved in each thermometer.

Some basic assumptions. 1. The relative positions of the lamp and the globe are the same as those of the sun and the earth.

2. The bent thermometer stem did not account for the differences.

3. The greater the heating effect, the more the expanding air will push liquid back into the beaker.

4. Rays reaching the upper thermometer bulb were more slanted.

5. There were no air leaks in the thermometers as they were set up.

TEST YOURSELF

Read the following statements carefully, If a statement is true, write the word *true* in the proper place on your answer sheet. If the statement is false, write the word or words on your answer sheet which should be substituted for the *italicized* ones to make the statement true.

1. Energy from the sun reaches the earth in a form called *heat*.
2. The earth's atmosphere *decreases* the heating effect of the sun's energy.
3. The blue color of the sky is caused by *large particles* in the air separating the light which makes blue from the rest of the sunlight.
4. On December 22 there are 24 hours of daylight within the *Arctic Circle*.
5. When the north pole of the earth's axis is tipped away from the sun, it is winter in the *Northern Hemisphere*.
6. When it is 2:00 P.M. Daylight-saving Time in New York, it is *10:00 A.M.* standard time in Los Angeles.
7. If a traveler crossed the International Date Line from east to west on Monday, it would be *Tuesday* after he had crossed the line.

PROBLEM 2. How does the moon affect us?

INFLUENCE OF THE MOON

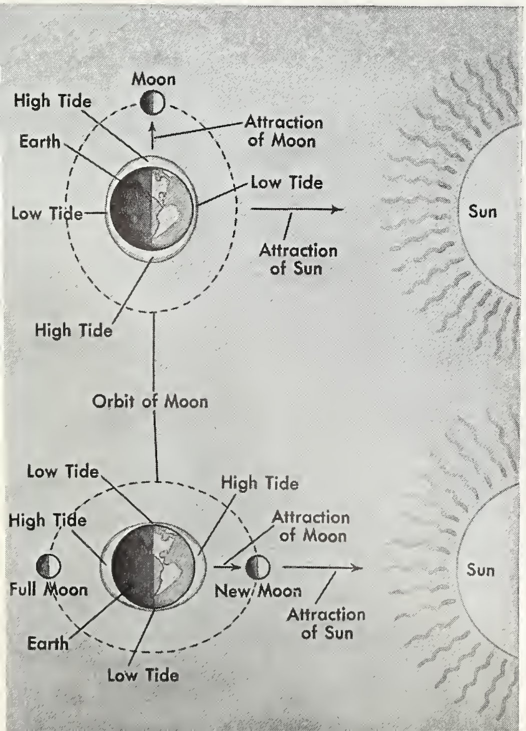
Crops, weather, and luck. Before accurate facts about the moon were discovered, man had many incorrect ideas or superstitions about the influence of the moon on human life. For example, he thought the weather could be predicted from various positions of the moon as it passed through its phases. A first glimpse of a new moon through the top of a tree or over the left shoulder was supposed to bring good luck. You probably have heard many other such beliefs for which there is no evidence. Let us look now at some of the ways in which it is definitely known that the moon affects the earth.

Solar eclipse. You will recall that the moon moves around the earth once in about 29 days. On most occasions the moon's orbit takes it slightly above or below a direct line to the sun. At least twice each year, and sometimes as often as five times each year, the moon passes directly between the earth and the sun. When this happens, the sun appears to be hidden behind the moon. We call this a *solar eclipse*. You may wonder how the sun, whose diameter is 400 times that of the moon, can be hidden by the moon. This is possible because the sun is about 400 times as far away from the earth as the moon is, and it therefore appears to be about the same size as the moon.

You will see on page 131 that an eclipse of the sun is actually the shadow which the moon casts on the earth when it comes between the sun and the earth. When the entire surface of the sun appears to be covered by the moon there is said to be a *total eclipse* of the sun. At that time the entire surface of the sun may be invisible to any one observer for as much as seven minutes. A total eclipse can be observed from only a small part of the earth's surface at any one time. To a larger area of the earth's surface, the sun appears to be only partially hidden by the moon. The area from which a *partial eclipse* could be observed is shown by the lighter shading in the drawing on page 131.

Astronomers on the basis of long and careful observation can predict the exact time of a solar eclipse and the exact area on the earth from which it will be visible. Since solar eclipses are not always total eclipses, there may not be a total eclipse every year. Eclipses have little direct effect upon our daily lives, but they are interesting to observe. Before the coronagraph was invented, astronomers could study the corona and the chromosphere of the sun only during a total eclipse, when the main surface of the sun was hidden by the moon's shadow. At that time the chromosphere looks like a bright red, narrow rim around the invisible sun. Even today astronomers travel to distant places to observe a total eclipse and make careful preparations long in advance in order to make the best use of the few minutes during which it is visible.

When the moon is in the position shown in the upper diagram, tides are lower than when the moon is in either of the positions shown in the lower diagram.



Lunar eclipse. When the earth is on a direct line between the sun and the moon, the moon runs into the earth's shadow and then it may become invisible; but usually it turns a coppery red color and is easily visible. This is called a *lunar eclipse*. An eclipse of the moon can be seen from any part of the earth from which the moon is visible. There are never more than three lunar eclipses in a year. Some years there are none.

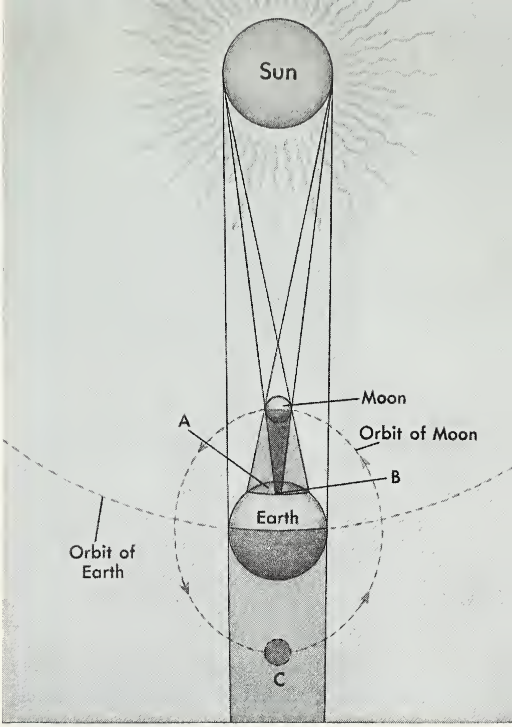
Tides. People who live near the ocean and those who enjoy ocean bathing know that twice every day the water along the shore rises as the tide comes in and falls as the tide goes out. When the water is rising, the tide is called *high* or *flood tide;* when it is falling, it is called *low* or *ebb tide*.

Though it has long been known that there is some connection between the moon and the tides, astronomers have found it difficult to give a complete explanation. We know, however, that the gravitational pull of the sun and the moon upon the earth tends to pile up the water as shown at left. Although the moon is much smaller than the sun, its tidal pull upon the earth is twice as great as that of the sun because it is much nearer the earth. The high tides are highest and the low tides are lowest when the moon and the sun are pulling together in a straight-line position with the earth. This happens twice a month when there is a new moon and when there is a full moon.

These tides are called *spring tides,* but the term *spring* has no reference to the season of the year. Twice each month, during the first quarter and the last quarter of the moon, the sun and the moon are at right angles to the earth (see page 130). Because they are then pulling upon the earth at right angles, the high tides are lowest high tides, and the low tides are highest low tides at that time. These tides are called *neap tides.*

If the moon and the sun were always in the same positions, high and low tides at any particular place would occur at the same time each day. But, the moon appears to revolve around the earth once in about 29 days. Because the position of the moon changes, the time of high and low tides at a particular port may be from a half hour to an hour and a half later each day. From careful observations made over many years, the time of high and low tides for any ocean port can be calculated and predicted with great accuracy. Tables based on these predictions are very valuable to fishermen and to navigators in launching and docking ships.

Lunar months. We have seen that the period of rotation of the earth upon its axis determines the length of the day, and the period of its revolution around the sun gives us the length of the year. The period in which the moon appears to revolve around the earth has also been used in reckoning time. It takes about 29½ days for the moon to pass through its four phases. This period, called the *lunar month,* was used by the Egyptians and is still used by the Jews and the Turks in reckoning time. Our calendar months do not correspond to the lunar months.



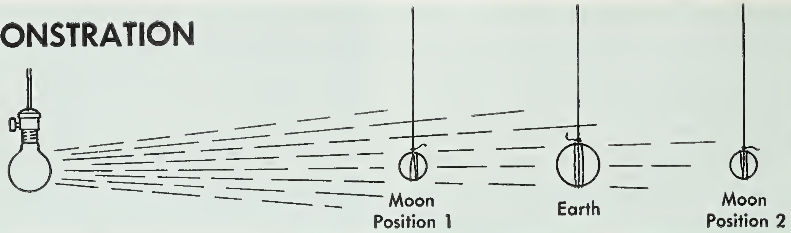
Positions of sun, moon, and earth during eclipses. In area A on the earth, there will be a partial eclipse, in area B a total eclipse, when the moon is in top position. When moon moves into position C, the earth shadows it, causing an eclipse.

SUMMARY

Many false beliefs and superstitions regarding the effects of the moon upon man have developed through the ages. Although facts have been discovered which disprove many of these incorrect ideas, some people still believe them.

The moon causes solar eclipses. The gravitational attraction of the moon is the principal cause of tides. The exact time of high and low tides can be predicted so that the most effective use can be made of tides in docking and launching ships. The lunar month has been used in reckoning time, but does not correspond to our calendar months.

DEMONSTRATION



Generalizations to be demonstrated. 1. When the moon passes directly between the earth and the sun, there is a solar eclipse.

2. When the earth is on a direct line between the sun and the moon, there is a lunar eclipse.

What you need. A 250-watt electric light bulb or lantern-slide projector; an orange or a rubber ball about equal in size to represent the earth; a ping pong or golf ball to represent the moon; and a piece of cardboard about 6 inches square if you plan to use the slide projector.

What to do. Arrange the lamp or lantern-slide projector in the position shown in the diagram. If a lantern-slide projector is used, cut a piece of cardboard as shown and put it into the lantern-slide holder. Attach strings to the balls representing the earth and moon so that they can be held in position from above with the string. Darken the room and turn on the lamp or slide projector. Suspend the "earth" and the "moon" in proper positions for a solar eclipse and observe. Rearrange the positions of "earth" and "moon" for a lunar eclipse.

Two assumptions in this demonstration. 1. Light behaves the same in our atmosphere as it does in space.

2. The relative positions of the sun, moon, and earth are the same in this demonstration as they actually are.

What does it mean? What happens to light reaching the earth when the moon passes directly between the earth and the sun?

What happens to light reaching the moon when the earth is in a direct line between the sun and the moon? Why isn't a solar eclipse visible from all places on the earth?

Why is a lunar eclipse visible over a larger area than a solar eclipse?

TEST YOURSELF

Write the answer to each of the following questions in the proper place on your answer sheet.

1. What heavenly body casts its shadow on the earth when a solar eclipse is seen?
2. About how long is a total eclipse visible from one place?
3. Why do astronomers often travel long distances to observe the sun during a total eclipse?
4. What is the position of the earth with respect to the sun and moon during a lunar eclipse?
5. What is the difference between a flood tide and an ebb tide?
6. What is the primary cause of tides?
7. What is the difference between a neap tide and a spring tide?

PROBLEM 3. How are the stars used in locating positions on the earth?

We have already seen that the earth is spherical. Imaginary lines can be drawn around it. The equator is an imaginary circle around the earth every point of which is halfway between the North and the South Poles. Like every other circle, it has 360 equal parts called degrees (see page 135). Any number of circles can be drawn around the earth through the North and South Poles, each containing 360°. On all these circles, the distance between the North Pole and South Pole is one-half the entire circle, or a semicircle, having 180°. The equator divides each semicircle into equal parts so that there are 90° between the equator and the North Pole and 90° between the equator and the South Pole (see drawing on page 135).

Positions north and south. Now suppose we draw around a globe of the earth lines that are 1° 2°, 3°, and so on, north of the equator until we reach the North Pole. We can draw similar lines until we reach the South Pole. Because all these lines are parallel to the equator and go around the earth, we call them *parallels of latitude* (*latitude* means "breadth"). We could then tell the distance in degrees north or south of the equator of any point that lies on one of these parallels. But to find the exact distance north or south of the equator of a point lying between, say, 45° and 46°, we need a unit smaller than the degree. Each degree has therefore been divided into 60 minutes (′), and each minute into 60 seconds (″), but these subdivisions are not the same as minutes and seconds of time. With these smaller units, distances on the earth's surface can be measured accurately. On page 135 you will see that lines have been drawn every 30° north and south of the equator. Line A is 30° north latitude, that is, it is 30° north of the equator. Line B is 60° south latitude. If a certain position were 65 degrees, 30 minutes, and 5 seconds south of the equator, its position would be written as 65°30′5″S. Using this system, you can now locate the north or south position of any place on a map.

Positions east and west. Though points X and Y shown on page 135 are both 60° north latitude, they are not in the same place. Y is east of X. Before we can locate a place exactly, we must be able to tell its position east or west as well as north or south. We have already seen that a great many imaginary circles can be drawn around the earth through the North and South Poles. Each line from pole to pole is called a *meridian*. At an international conference in 1884, the meridian passing through Greenwich, England, was accepted as the Prime Meridian and its position was designated at 0 degrees. Every point on the earth lies on some meridian. Its position is stated as the number of degrees it lies east or west of the Prime Meridian. The distance east or west of the Prime Meridian is called *longitude*. On page 135 point A is 30° east longitude and point B is 75° west longitude; that is, A is 30° east of the Prime Meridian, and B is 75° west of it. If we travel halfway around the earth either east or west from the Prime Meridian, we come to a position 180° from the Prime Meridian. This is the approximate location of the International Date Line.

The exact position. Now we can locate the exact position of any place on the earth by giving its latitude and its longitude. New York, for example, is 40°49′ N (north latitude) and 73°58′ W (west longitude); San Francisco is 37°47′ N and 122°26′ W; and Denver is 39°41′ N and 104°57′ W. Ordinarily we do not need to locate cities by their latitude and longitude because their positions are printed on most maps. However, a ship in the middle of the Pacific Ocean would indicate its position by giving its exact latitude and longitude. The method by which man is able to determine his position in the air and on the sea is called *navigation*.

NAVIGATION

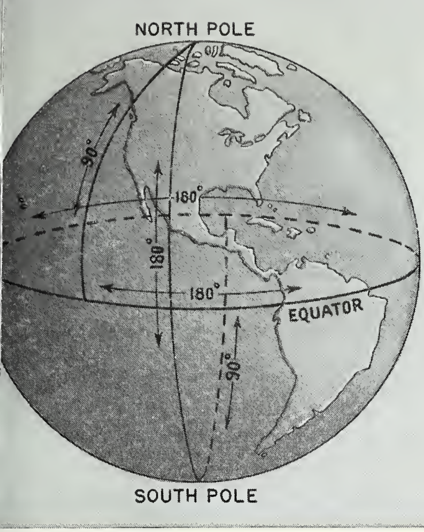
Stars to locate position. Maps or charts with parallels of latitude and meridians of longitude printed upon them are used by the navigator to aid in directing his ship or airplane to its destination. When he cannot see the land, he may use certain bright stars, or the sun, moon, or planets, to locate his exact position. He does this from time to time as he plots the course of his voyage on the chart. Essentially, the navigator needs three things to use the stars in that way. These are:

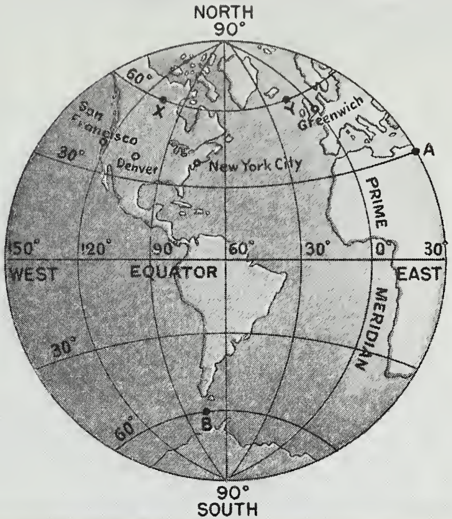
Sextant (see page 119)—to measure the *altitude* of the star at his position. The altitude of a star is its distance above the *horizon* (the line where the earth and sky seem to meet).

Chronometer—a very accurate clock which always shows Greenwich Time. This is used to find the exact Greenwich Time when the above altitude is measured.

Almanac—a book of tables, published each year, which shows the exact position in the sky of the sun, moon, or planets, or the stars the navigator may use. From the almanac, the navigator can find the actual position of the body he is observing at the exact Greenwich Time when the altitude was measured.

When the navigator knows the exact location of a star, or one of the other bodies he can use, he can also find the latitude and longitude of the point on earth directly under it. Since he knows the altitude of the body from his ship (measured with the sextant), he can determine how far his ship is from that position on earth. Actually, he can be in many different places and still be the





same distance from that position, so he must repeat the process with at least two bodies to know exactly where the ship is located. For each body he observes, he lays out a circle on his chart, with the center of the circle at the known point directly under the body and with his distance from the point as the radius of the circle. His position will be at the one point on his chart, close to where he is sailing, where these circles cut through each other.

Using the earth's magnetic pole. The mariner's compass enables a navigator to tell in which direction his ship is traveling. The needle of the compass is attracted by the earth's *magnetic pole,* which is situated near the North Pole. It therefore points in a northerly direction. Though it does not always point directly toward the North Pole, differences between true north and the direction in which the compass needle points from different places on the earth have been determined by long and careful observation. By allowing for these differences it is possible to determine true north from the direction of the mariner's compass.

Importance of accurate navigation. Since airplanes travel very fast and with limited supplies of gasoline, it is extremely important for them to go directly to their destinations. To insure this, all navigational instruments must be highly accurate. By using such accurate instruments to make precise calculations, a navigator can take an airplane or a ship directly to its destination even though it is a tiny island in the vast ocean.

SUMMARY

Although the earth is a small body compared with stars in the universe, the earth is not so small to man, and he has often experienced difficulty in determining his position and that of objects upon it. The regularity with which the earth and the stars move within the universe has made it possible for the stars, including the sun, to be used as markers in helping man find his way around. He has devised instruments which aid him in making observations so that he can determine his position on the earth accurately.

TEST YOURSELF

Select the ending which best completes each statement and write its letter in the proper place on your answer sheet.

1. The number of degrees contained in an imaginary circle around the earth from the North to the South Pole is (a) 0; (b) 90; (c) 180; (d) 360.
2. An imaginary line drawn around the earth so that all points on it are the same distance from the equator is called (a) a parallel of latitude; (b) the International Date Line; (c) longitude; (d) the Prime Meridian.
3. An imaginary line drawn from the North to the South Pole and passing through Greenwich, England, is called (a) a parallel of latitude; (b) the International Date Line; (c) longitude; (d) the Prime Meridian.
4. The number of degrees separating the Prime Meridian from the International Date Line is about (a) 90; (b) 180; (c) 270; (d) 360.
5. A sextant is used to measure (a) time; (b) altitude of a star; (c) direction to the North Pole; (d) speed.
6. A chronometer is used to measure (a) time; (b) altitude of a star; (c) direction to the North Pole; (d) speed of rotation of earth.

CHAPTER ACTIVITIES

HOW DO DISTANT BODIES AFFECT US?

1. One of the important generalizations developed in this chapter is: "The sun is the principal source of energy on the earth." On your answer sheet, write the letters of the statements below which support this generalization. **Do not write in this book.**

   a. The sun is 93,000,000 miles from the earth.
   b. Green plants use light to produce food from carbon dioxide and water.
   c. A solar eclipse is the shadow which the moon casts upon the earth.
   d. The evaporation of water from the surface of the earth makes water available as a source of power.

2. A number of the beliefs which some people have about the effects of the moon upon the earth are stated below. In the proper place on your answer sheet, write the letter of each belief supported by facts.

   a. The moon is so far away that it cannot have any effect upon the earth.
   b. The gravitional pull of the moon is the principal cause of the tides.
   c. It is possible to predict weather by studying the moon.
   d. The moon reflects radiant energy from the sun to the earth.

3. In this chapter you learned that the sun and other stars are observed by navigators in determining their position on the earth. In the proper place on your answer sheet, write the letters of the following statements which describe conditions making it possible for navigators to use the sun and stars for the above purpose.

a. The position of stars on any future date can be predicted.
b. The atmosphere affects the amount of energy which the earth receives from the sun.
c. Maps with parallels of latitude and meridians of longitude aid in locating one's position on the earth.
d. The stars observed by navigators differ in temperatures.

SELECT RELIABLE INFORMATION

In a discussion of the effects of heavenly bodies upon people, it was claimed that a person's future is determined by the position of planets on the date of his birth. A number of those taking part in the discussion questioned this belief. On your answer sheet, write the letters of the following statements which describe reliable ways of checking the accuracy of this belief about the influence of the planets.

a. Accept evidence from only the most recent books on astrology.
b. Keep an accurate record of what happens to people born on the same date.
c. Ask an astronomer what evidence there is to support this belief.
d. Use the opinions of those who visit an astrologer regularly to learn about their future.
e. Compare what different astrologers say about the future of the same person.

UNIT ACTIVITIES

RELATE FACTS TO MAN'S ACTIVITIES

A number of activities of people are listed below, followed by a list of facts which man has discovered about the universe. On your answer sheet beside the number of each activity write the letter or letters of facts which are most important in explaining why or how it is carried on.

ACTIVITIES OF MAN

1. He raises green plants for food.
2. He studies the sun during a solar eclipse.
3. He locates his position on the earth.
4. He turns his watch ahead as he travels.
5. He selects clothing suitable for each season.
6. He hangs clothes outside to dry.
7. He locates telescopes on mountain tops.
8. He uses Daylight-saving Time in the summer.
9. He admires the colors in sunsets.
10. He takes pictures with a camera.
11. He goes south for the winter.
12. He predicts the time of high and low tides.
13. He measures distances on the earth in degrees.

- a. The movements of the heavenly bodies can be accurately predicted.
- b. Gravitational forces exist between heavenly bodies.
- c. The earth is approximately a sphere.
- d. The earth rotates on its axis.
- e. The earth revolves around the sun.
- f. The earth's axis is tilted 23½°.
- g. The sun supplies the earth with radiant energy.
- h. Visible light is made up of several different colors.
- i. Some of the radiant energy from the sun is absorbed by the atmosphere.
- j. Sometimes the moon casts a shadow upon the earth.
- k. The earth has magnetic poles.

INCREASE YOUR UNDERSTANDING

1. Prepare a report on one or more of the following topics:
    - a. Early astronomers
    - b. Astrology today
    - c. The 200-inch telescope
    - d. The Schmidt telescope
    - e. The coronagraph
    - f. A rocket trip to the moon
    - g. Sunspots
    - h. Astronomy as a vocation
2. Participate in a panel discussion on "The Value of Astronomy to Man."
3. Locate on a star map as many constellations as you can.
4. Draw diagrams of the following:
    - a. A reflecting and a refracting telescope
    - b. Great circle routes flown by airplanes in transcontinental flights
5. Describe the appearance of the moon as seen through a pair of field glasses.
6. Prepare a bulletin board exhibit of the following:
    - a. The 200-inch telescope and some of the pictures taken with it
    - b. Several constellations as they would appear in the sky, by using small white buttons on blue paper
    - c. The way the earth is affected by radiant energy from the sun
    - d. The formation of tides on the earth
7. Visit if possible an observatory to find out how astronomers work.
8. Collect a list of superstitions and misconceptions about the effect of heavenly bodies upon man.
9. Prepare a superstitions-and-misconceptions test to be given to other classes. Compare the test results obtained.
10. Prepare a quiz program on facts about the universe and present it during a school assembly.
11. Visit a planetarium to observe one of the demonstrations.

READ ABOUT THE UNIVERSE

The following are references which you may find helpful in increasing your understanding of the universe:

Bendick, Jeanne. *How Much and How Many*. New York: Whittlesey House, 1947.

There are two sections, one on measurements of time and another on measurements in navigation, pages 103–124, that would be extremely interesting for you.

Brindze, Ruth. *The Story of the Calendar.* New York: The Vanguard Press, 1949.

A dramatic and fascinating story, illustrated with colored pictures of how man developed the modern calendar.

Caidin, Martin. *Worlds in Space.* New York: Henry Holt and Company, 1954.

Many photographs and drawings help tell the history of rocket development and show the steps by which man may some day travel to other planets.

Carlisle, Norman, and Nelson, Eugene. *The Modern Wonder Book of Ships.* Philadelphia: The John C. Winston Company, 1947.

Chapter 17 of this book deals with the work of the ship's navigator and the instruments he uses.

Clarke, Arthur C. *The Exploration of Space.* New York: Harper & Brothers, 1951. Also available in a pocketbook.

A scientifically accurate discussion of all aspects of space travel by the Chairman of the British Interplanetary Society.

Coggins, Jack, and Pratt, Fletcher. *By Space Ship to the Moon.* New York: Random House, Inc., 1952.

The first steps that will probably be taken in space travel. A discussion of the reasons for space travel, how it may be financed, and what living conditions to expect on the moon.

Goodwin, Hal. *The Real Book About Stars.* New York: Garden City Books, 1951.

This is a simplified introduction to stars. It contains some very good charts to help the young star-gazer.

Goodwin, Harold Leland. *The Science Book of Space Travel.* New York: Franklin Watts, 1954.

A presentation of the various arguments, both pro and con, concerning the future of rockets, space platforms, nuclear drive, and the medical and psychological problems of man in space.

Heinlein, Robert. *Red Planet.* New York: Charles Scribner's Sons, 1949.

If you like science-fiction stories, here is a thriller about the adventures of two American boys on Mars.

Hood, Peter. *Observing the Heavens.* New York: Oxford University Press, 1952.

Contains many facts on general astronomy including instructions on how to make a small telescope and how to use it.

Hoyle, Fred. *The Nature of the Universe.* New York: Harper & Brothers, 1950.

An interesting and easy to read interpretation of the nature of the universe by a noted British astronomer.

Lum, Peter. *The Stars in Our Heaven.* New York: Pantheon Books, Inc., 1948.

The myths and fables about the constellations are told in a manner you will long remember.

Mayall, R. N., and Margaret L. *Skyshooting: Hunting the Stars with Your Camera.* New York: The Ronald Press Company, 1949.

How to have fun photographing the heavens.

Menzel, Donald H. *Our Sun.* New York: Doubleday & Company, 1949.

Supplies answers to many questions about the sun not generally found in other popular books on astronomy.

Moore, Patrick. *Guide to the Planets.* New York: W. W. Norton & Company, 1954.

A description of the planets and their satellites together with discussion of their possibilities as supporters of life and as way-stations for space tourists.

Poole, Lynn. *Your Trip into Space.* New York: McGraw-Hill Book Company, Inc., 1953.

Fascinating, accurate information about what space travel actually will mean to everyone of us.

Reed, Maxwell W. *Patterns in the Sky.* New York: William Morrow and Co., 1951.

The myths of the 25 most familiar constellations are told along with diagrams of the constellation figures.

Reed, Maxwell W. *The Stars for Sam.* New York: Harcourt, Brace & Company, 1931.

An exciting book about astronomy written for young people of your age.

Skilling, William T., and Richardson, Robert S. *Sun, Moon and Stars: Astronomy for Beginners.* New York: Whittlesey House, 1946.

Part V of this book contains interesting information about astronomers and observatories.

Williams, Lou. *A Dipper Full of Stars: A Beginner's Guide to the Heavens.* New York: Follett Publishing Company, 1944.

The charts in this book will help you locate constellations in the sky.

Woodbury, David O. *The Glass Giant of Palomar.* New York: Dodd, Mead & Company, 1948.

All about the 200-inch telescope and how it works.

White, Anne Terry. *All about the Stars.* New York: Random House, Inc., 1953.

This is a beginner's book on the essentials of astronomy.

Wright, Helen. *Palomar, the World's Largest Telescope.* New York: The Macmillan Company, 1952.

This book traces the development of the telescope from Galileo in 1610 to the huge 200 inch telescope at Palomar.

Zim, Herbert S. and Baker, Robert H. *Stars.* New York: Simon and Schuster, 1951.

A pocket guide to constellations, sun, moon, planets and other features of the heavens containing 150 illustrations in color.

Courtesy LIFE *Magazine (c)* TIME INC.

Space contains many types of radiant energy. Light from the stars caused the white streaks, while the antenna captured radiant energy of another type, radio waves, to give scientists an additional "window" through which to look at the stars.

unit 4 RADIANT ENERGY

EVER since man began to be a thinking being, he has tried to find out as much as possible about the world and has used his discoveries to make life easier for himself. Science has come to be recognized as one of man's most effective means for achieving success in his effort to use the world's resources, but science itself began in a very humble way. In the beginning man's discoveries about the world were very simple and were used quite directly, as in the control of fire, the making of primitive tools, and so on. Also, in early times the discoveries were about things that could be seen or touched. As time went on, man learned to make accurate records and use them as tools for his brain. This was one of the beginnings of science, and it was a great promoter of thought. When science and man had advanced to this stage, man could stop wondering and begin really to make discoveries about things he could not see. One of the most important of these things is energy.

Probably one of man's greatest triumphs came when he recognized that a number of types of energy, which he had previously thought were unrelated, were in reality closely related to each other. Recognizing this close relationship, he was able to gain a greater understanding of the different types of energy, to state his understanding more simply, and to use these types of energy effectively and in many ways.

Today we group these many related types of energy under one major heading, radiant energy. Radiant energy includes, among others, such types of energy as visible light, two types of invisible light, one known as infrared and the other as ultraviolet, radio waves, X-rays, and gamma rays. These types of energy have been grouped together because they are fundamentally the same, even though each one differs from the other in some ways.

This unit has been planned to help you see the unity of these types of energy as well as their differences. You will learn what scientists believe the nature of radiant energy to be, and some of the ways in which all types are similar. You will also learn how the types differ from each other and how man has made extremely efficient use of these differences.

Although the sun is the direct source of much of the radiant energy we use, scientists have discovered other ways of producing radiant energy as well as new uses to which it may be put.

chapter 8 OBTAINING RADIANT ENERGY

FOR hundreds of years the only types of radiant energy available to man were those that came from the sun and from fires. Since he did not understand the nature of radiant energy, he had no idea it might be possible to produce other types. In 1873 James Clerk Maxwell, a Scottish scientist, suggested a new theory for the nature of light. His theory not only explained the nature of light much as we do today, but also suggested that there might be other types of radiant energy as yet unknown to man. People paid little attention to Maxwell's ideas at first because no one was able to prove his theory to be true. But in 1887 Heinrich Hertz, a German scientist, produced and used a new type of radiant energy known today as Hertzian or radio waves. Maxwell's theory could no longer be ignored. And once it was accepted, scientists soon discovered still other types of radiant energy and developed a more accurate idea of its nature.

PROBLEM 1. What are the characteristics of radiant energy?

RADIANT ENERGY

The term *characteristics* refers to the appearance or behavior of a person or thing. Usually some of the characteristics of a substance can be determined by observing it. But since radiant energy cannot be seen, it is impossible to describe its appearance. Many of its characteristics must therefore be determined by the *if—then* method. Scientists observe what radiant energy does, and from these observations they try to describe it. This problem is intended to help you understand what scientists think radiant energy is.

Travels through space. It is believed that most of the space in the universe contains almost no matter. Yet radiant energy from the sun travels almost 93,000,000 miles through space in reaching the earth. In 1946 scientists were able to send a radio wave to the moon. Even after most of the air has been removed from a glass bottle, light will pass through the bottle as well as it did before. These and similar facts which scientists have observed indicate that radiant energy can travel through space. Matter need not be present. This is one characteristic of all types of radiant energy.

Travels at the speed of light. Light is one type of radiant energy. We have already learned that light travels through space at about 186,000 miles per second, or in the metric system, 330,000,000 meters per second. At this speed it could travel around the earth about seven times in one second. It was natural, therefore, for early scientists to believe that light went from one place to another instantly.

All types of radiant energy—radio waves, infrared rays, and visible light—travel at the same tremendous speed. Because of this, radio waves are an almost instantaneous means of communication. In a fraction of a second they can reach any place in the world.

"Waves" of radiant energy. As early as 1800 some scientists suggested that light traveled as a series of waves somewhat like waves in water. But, they asked, what carried the waves from place to place? As far as they could determine, light traveled easily through space. They thought there must be some substance in space in which light waves traveled. They called this imaginary substance *ether*. Radiant energy waves, they thought, traveled in ether as water waves travel in water. Scientists long ago discarded the idea that there is ether in space. Though we call radio waves "ether waves," we know they are not "waves in ether." Radiant energy waves, though sometimes compared with water waves, are unlike anything else in the universe.

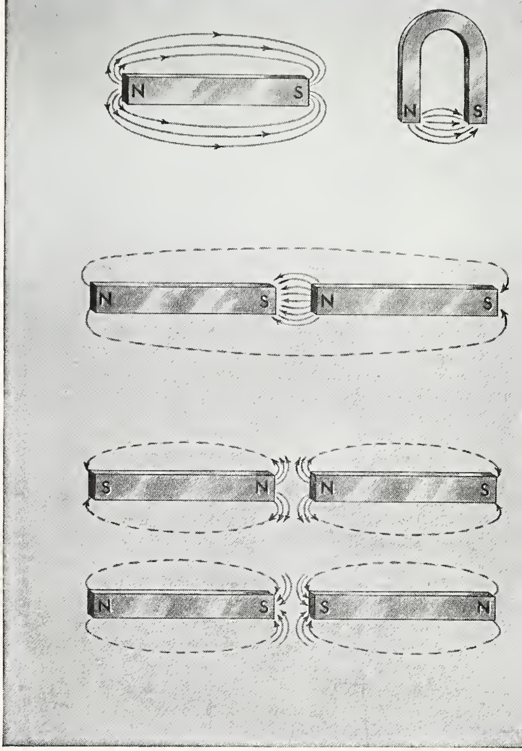
WAVES OF RADIANT ENERGY

Magnetic fields. You have probably played with a *magnet* and discovered that when it is brought near a metal object, such as an iron nail, the nail is pulled, or *attracted,* toward it, even though it does not touch the nail. The force of the magnet extends through space between the magnet and the nail. The space around the magnet, together with the forces acting through the space, is called a *magnetic field*. As shown on page 145, the forces around like magnetic poles repel each other while those around unlike magnetic poles attract each other. Therefore, unlike magnetic poles attract, while like magnetic poles repel each other.

Electric fields. A hard rubber rod when rubbed with fur or wool will attract small bits of paper. It does not have to touch the bits of paper; it pulls them through space. Such a rod is said to be *electrically charged.* The force acts on the paper through the space around the rod. The space, together with the forces acting throughout it, is called an *electric field.* A glass rod rubbed with silk will also become electrically charged. When an electrically charged glass rod is brought near an electrically charged rubber rod, the two rods tend to attract each other. The electrical charge on the rubber rod is called a *negative charge;* that on the glass rod is called a *positive charge.* When two negatively charged rubber rods are brought together they repel each other; two positively charged glass rods likewise repel each other. Thus electric fields, like magnetic fields, may attract or repel each other.

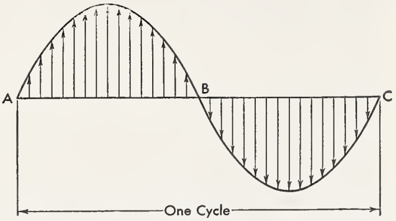
Electromagnetic waves. As we have just learned, both magnetic and electric fields exert a force through space. The force may be exerted in one direction as an attracting force, or in the opposite direction as a repelling force. These forces of electric and magnetic fields act through space whether or not there is anything present for them to attract or repel.

Waves of radiant energy are believed to be electric and magnetic fields of force traveling through space. Thus they may be called *electromagnetic waves* of radiant energy. You will learn more about the electric and magnetic nature of radiant energy in physics.



One end of a magnet is called a north (N) pole, the other a south (S) pole. The arrows represent forces in the magnetic fields. By agreement among scientists, the forces are said to leave the N pole and enter the S pole.

The term *wave cycle* indicates the changes in direction of the electric or the magnetic forces which make up radiant energy. Although both fields are present in radiant energy waves, for convenience we will consider only the magnetic field as represented in the diagram on page 146. The curved line between A and B represents an electromagnetic force in one direction. The arrows represent the strength of the force in the wave. The line is curved to show that the strength of the force increases and then decreases. The curved line between *B* and *C* represents

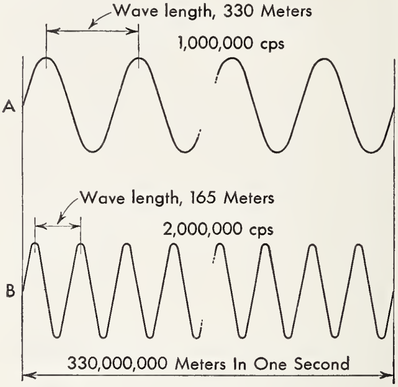


Wave of radiant energy.

an electromagnetic force in the opposite direction. This force also increases and decreases. As radiant energy travels, its electromagnetic forces act first in one direction and then in the opposite direction. This occurs over and over again many times per second as radiant energy travels through space. When the action of forces in one direction and then in the opposite direction are complete, the radiant energy is said to have passed through one wave cycle.

Frequency. *Frequency* refers to the number of changes of any kind taking place in a certain stated time. Thus frequency applied to radiant energy describes the number of cycles a wave of radiant energy completes in one second. Types of radiant energy differ mainly in their frequency. If a radiant energy wave completes 60 cycles in one second, its frequency is said to be 60 cycles per second, often abbreviated c.p.s. The frequency of most radiant energy waves is so high that it is stated in *kilocycles* (1000 cycles) or *megacycles* (1,000,000 cycles) per second. The average radio can receive radio waves ranging from 1500 to 500 kilocycles, the divisions on the dial indicating frequencies between these limits. The use of radio waves of different frequencies in communications will be discussed in Unit Thirteen.

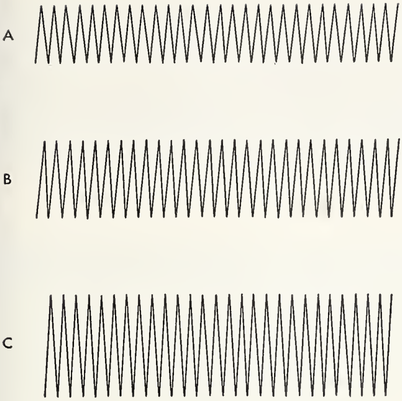
Wave length. *Wave length* expresses the distance through which a wave travels during one cycle. Given the frequency of a radiant energy wave, you can easily determine its wave length, as shown in the following diagram. It is apparent that as the wave length of radiant energy increases, its frequency decreases.



A and B represent radiant energy waves traveling from left to right. To determine the wave length of A, divide the distance traveled in one second (330,000,000 meters) by the frequency (1,000,000 c.p.s.) to get 330 meters as the wave length. When the frequency increases as at B, the wave length becomes less.

Amplitude. *Amplitude* means the strength of the electric and magnetic fields in a wave of radiant energy. In the drawing in column 1, the longest arrow represents the greatest strength, or amplitude, of the wave.

When the strength of a wave of radiant energy is low, the wave is said to have small amplitude. When the strength of the field is increased, a wave of larger amplitude is produced. Amplitude is used most often in describing the lower frequency waves, such as radio waves.



A, B, and C represent radiant energy waves of the same frequency. A has least amplitude, C greatest.

For example, when a radio station increases its power, it produces waves of greater amplitude and thus sends radio waves with stronger electric and magnetic forces into the space around it. This makes it easier for more people to hear the station on their radios. Increasing the amplitude does not change the frequency or the wave length of a particular radio wave.

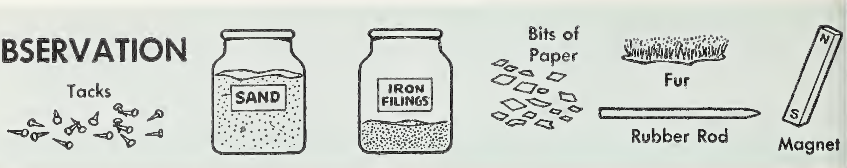
The wave theory and the particle theory of radiant energy. By assuming that radiant energy travels as waves, much of its behavior can be explained. However, some of its behavior, such as the action of light in producing electricity in a television camera, cannot be explained by the wave theory. This effect can be explained by assuming radiant energy to contain particles, somewhat like small bullets, traveling at tremendous speed. It was difficult for scientists to see how radiant energy could act as both waves and particles. For many years some scientists favored the wave theory and others favored the particle theory. Finally, in 1924, a French scientist, Louis de Broglie, suggested that moving particles have waves associated with them. So much evidence has accumulated since 1924 to support this idea that it is now widely accepted by scientists. How can something appear to be both particles and waves at the same time?

Imagine yourself standing in a field of wheat with the wind blowing. Looking over the field as a whole, you see waves moving across it. But when you look at the wheat near you, you see the field as composed of individual stalks (particles) of wheat. Or perhaps you have watched the wind blow the rain during a heavy rainstorm. As you look down the street or across an open field, you can see the waves of rain moving along. But you know that the waves are composed of many raindrops. These two examples show that it is not impossible to observe something moving as waves even though it is composed of individual parts.

SUMMARY

Radiant energy is believed to be electric and magnetic fields. It travels through space at the highest speed known to man. Sometimes its behavior indicates it must be made up of waves, but at other times it seems to consist of particles. The forces making up radiant energy change their direction and strength in definite wave cycles. The frequency of wave cycles distinguishes one type of radiant energy from another. The strength of the electric and magnetic forces making up a particular radiant energy wave can be changed without changing its frequency.

OBSERVATION

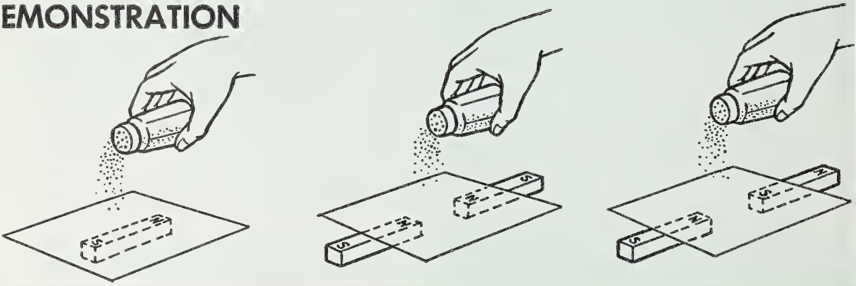


What to observe. The action of magnetic fields and electric fields upon various objects.

How to observe it. Mix together some sand, iron filings, small tacks, bits of paper, and bits of fur. Place the mixture upon a flat wooden surface such as a table top. Bring a magnet close to the mixture. Which objects are affected by the magnetic field? Rub a rubber rod with fur and bring the rod close to the mixture. Which objects are affected by the electric field?

Interpretation of your observation. Write two sentences describing the action of magnetic and electric fields upon the objects tested.

DEMONSTRATION



Generalizations to be demonstrated. 1. Magnetic fields are strongest nearest the pole of a magnet.

2. Like magnetic fields repel each other, while unlike magnetic fields attract each other.

What you need. Two bar magnets; iron filings; sheet of white cardboard.

What to do. Sprinkle iron filings on the card board while it is resting on the magnets arranged as shown above.

What to observe. 1. After iron filings are sprinkled over one of the bar magnets, how are they arranged? Where are most of them?

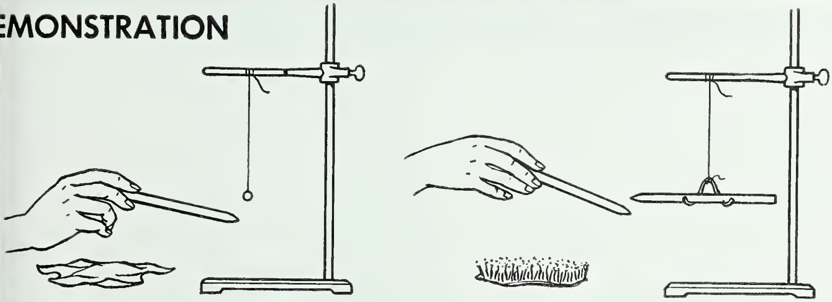
2. How are the iron filings between the two like poles arranged?

3. In what way does the arrangement of filings over unlike poles differ from that over like poles?

A basic assumption. The patterns formed by the iron filings show the magnetic fields of the magnets.

What does it mean? How does the arrangement of the iron filings give evidence to support the generalization in this demonstration?

EMONSTRATION



Generalization to be demonstrated. Like electric fields repel each other, while unlike electric fields attract each other.

What you need. Two hard rubber rods; cat's fur or wool; pith balls or small bits of paper suspended by a thread; a double wire hook across which a rubber rod can be placed; thread to suspend the double wire hook; glass rod; silk; ringstand.

What to do. 1. Grasp the blunt end of a rubber rod with one hand and slide the other hand over the remaining surface of the rod. Now bring the point of the rod near a suspended pith ball, as at A, and observe the effect upon the pith ball. Rub the rod briskly with fur. Move the rod back and forth about an inch below the pith ball and observe. Do not allow the pith ball to touch the rod.

2. Suspend the double wire hook by a single thread, as at B. Charge a rubber rod by rubbing it with fur, and lay it on the double wire hook, being careful not to touch the charged end of the rod. Now charge another rubber rod and bring it near the first one and observe its effect. Next charge a glass rod by rubbing it with silk, bring it near the suspended rubber rod, and observe.

3. Strongly charge a rubber rod and attract a suspended pith ball with it. Let the two remain in contact for a short time. (The pith ball should receive a charge similar to that of the rod and upon so doing will swing away from the rod.) After the pith ball leaves the rod, try

to touch it with the rod. Now try to touch the pith ball with a charged glass rod.

What to observe. 1. In what way does the action of the pith ball, when approached by a rod rubbed with fur, differ from its action when approached by a rod which has been touched by the hands?

2. What is the action of two charged rubber rods? What is the action of one charged rubber rod toward a charged glass rod?

3. In what way does the action of a charged pith ball, when approached by a charged rubber rod, differ from its action when approached by a charged glass rod?

Some basic assumptions. 1. The charge on a rubber rod rubbed with fur is unlike that on a glass rod rubbed with silk.

2. The action of the pith ball and of the suspended rubber rod shows the action of electric fields to each other.

What does it mean? How does the action of the charged bodies used in this demonstration support the statement that "like electric fields repel each other while unlike electric fields attract each other"?

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words on your answer sheet which should be substituted for the *italicized* ones to make the statement true.

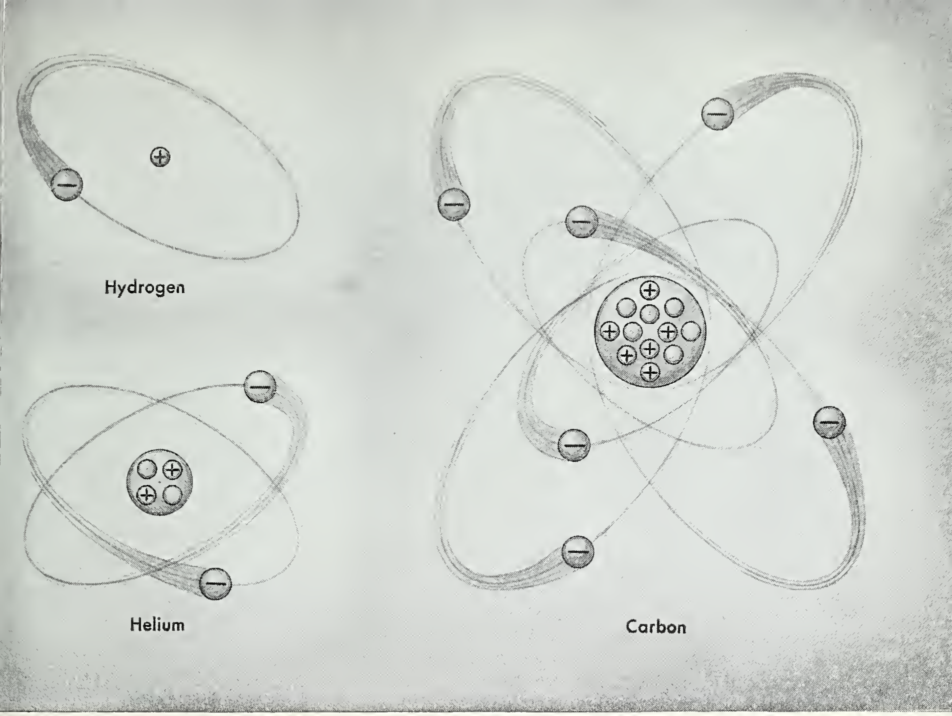
1. Radiant energy *can* travel through empty space.
2. The strength of the electric or magnetic fields in a radiant energy wave is known as its *amplitude*.
3. If two magnets are placed with their north poles close to each other, the magnetic fields will *attract* each other.
4. A hard rubber rod rubbed with fur takes on a *positive* charge.
5. The number of cycles per second of a radiant energy wave is known as the *frequency* of the wave.

PROBLEM 2. What is the source of radiant energy?

THE ATOM

Man has not always understood the nature or the source of radiant energy, but lack of knowledge has not prevented him from enjoying its benefits. For ages he has used radiant energy from the sun and from fires on the earth. Only during the last century has he been able to produce and use other types of radiant energy, such as radio waves, X-rays, and ultraviolet rays. They have undoubtedly been present on the earth for many ages, but scientists had to discover them and learn to control them in order to put them to practical use.

After radio waves, X-rays, and ultraviolet rays had been discovered, scientists became more curious about the



These diagrams of some of the parts of atoms help us get a better understanding of their probable structure. Of course, no one knows what the inside of an atom really looks like. Only one orbit of many possible ones is shown for each electron.

source of radiant energy. Many experiments were done to find out the sources of the different types of radiant energy. The facts learned from these experiments pointed to a single source, the atom.

Atoms of chemical elements. The atom is the smallest particle of a chemical element. Atoms are so tiny it is difficult to imagine how small they are. If 250,000,000 hydrogen atoms, the smallest atoms known, were placed side by side, they would form a line only one inch long. Atoms of other elements are believed to be larger than the hydrogen atom, but even uranium atoms, the largest atoms found in nature, are so small that a row of 100,000,000 of them would measure no more than an inch. Small as these atoms are, they are made up of even smaller parts.

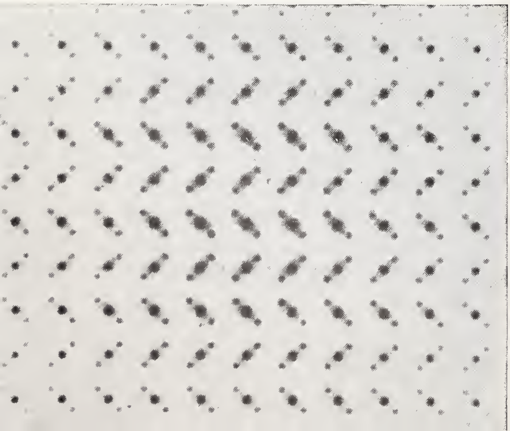
Inside the atom. At the very center, or core, of each atom there is apparently a compact, heavy part called the *nucleus,* which seems to give the atom most of its weight. The nucleus is thought to contain two kinds of grainy material, one called a *proton,* the other a *neutron.* A proton is estimated to be about $\frac{1}{200{,}000{,}000}$ the size of a hydrogen atom, and it has a positive electrical charge. The neutron is thought to be about the same size as the proton, but it does not have an electrical charge. A hydrogen atom has one proton in its nucleus. The next heavier atom, *helium,* has two protons. Each succeeding heavier element has one more proton in its nucleus. Most of the atoms also have one or more neutrons in their nuclei. Although scientists have discovered a number of other particles that must be part of the nucleus, they have not yet learned what part they play in the make-up of the atom. It is evident that even though the atom is very small, it is complex.

Besides a nucleus, each atom has another part called an *electron.* An electron is larger than a proton, but it weighs much less. Thus while the proton is small, compact, and heavy, the electron is large, thin, and light. The electron carries a negative electrical charge.

There are as many electrons in an atom as there are protons in the nucleus of that atom. The electrons swing about the nucleus, as shown on page 151, in one of the many possible paths (or orbits) it may occupy. Since the electrons are negatively charged and the protons positively charged, they are attracted to each other. It is this force of attraction that prevents the electrons from flying away from the nucleus as they swing about it. The number and arrangement of the protons and electrons within an atom seem to determine whether it will be hydrogen, tin, gold, or some other element.

These are atoms of a crystal of iron pyrite (FeS_2) often called Fool's Gold. Note the orderly arrangement of the atoms. The large atoms are Fe with 26 electrons while the smaller ones are S with 16 electrons. The images are magnified more than 2,000,000 times with an X-ray microscope.

Photo by Prof. M. J. Buerger, Massachusetts Institute of Technology



Protons, neutrons, and electrons are extremely small compared with the total size of an atom. The distances between the particles are many times as great as the sizes of the particles. Most of the atom is therefore space. Each atom may be thought of as a miniature solar system with the nucleus representing the sun and the electrons the planets.

Electrons travel around the nucleus of the atom in one or more orbits (see page 151). As they circle the nucleus, they seem to wobble about within their orbits rather than to follow a definite path. Electrons traveling in orbits nearest the nucleus have less energy than those traveling in orbits farther from the nucleus. Under certain conditions electrons may jump from one orbit to another.

It may help keep the ideas about atomic structure clearly in mind if we consider that what we see depends upon our basis of comparison. For example, to us the earth appears to be standing still, yet if it were observed from a point out in the universe, it would seem to have several motions. To the unaided eye the edge of a razor blade appears to be smooth, but when viewed through a microscope it is seen to be very rough. The wood used in the construction of our homes to us seems to be solid, but a radio wave passes through it as if it weren't there. Steel appears extremely solid both to us and to the radio wave, but an X-ray can pass through it. In making statements about the nature of the universe or the atom we must always consider the size and position of the object under consideration in relation to the observer.

Radiant energy from electrons. Moving electrons are thought to be the part of the atom responsible for most types of radiant energy. Electrons sometimes move from one atom to another. Such an interchange of electrons produces the radiant energy of the lower frequencies found in radio waves. Radiant energy of some higher frequencies is produced by electrons jumping from outer orbits into orbits nearer the nucleus of the same atom.

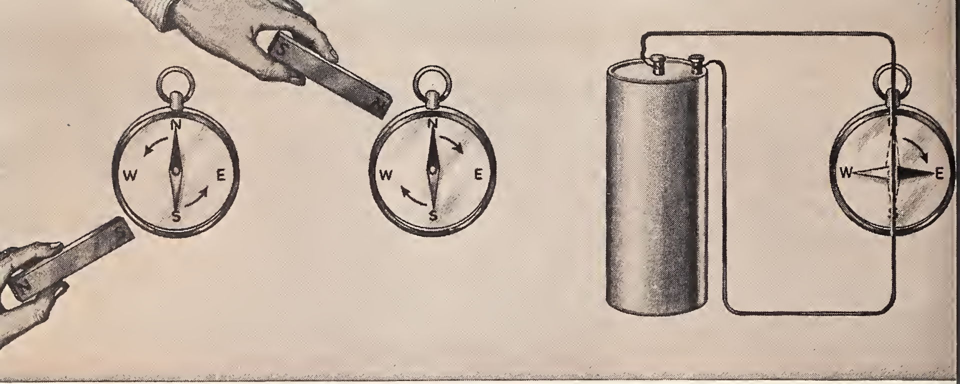
You will remember that a radiant energy wave consists of constantly changing electric and magnetic fields. Since electrons produce radiant energy waves, they must be able to produce both electric and magnetic fields. To understand how moving electrons can be the source of radiant energy we must first consider the nature of electricity.

ELECTRICITY

Currents of electricity. Though electricity was discovered about 600 B.C., for 2,500 years its nature was not understood. In 1897 Sir J. J. Thomson, an English scientist, discovered the electron and reported on its behavior. Scientists now agree that it is the movement of electrons from one atom to another that is the electric current. A battery or some other device causes electrons to move. The electric current thus produced runs motors, produces light, operates toasters, and does many other kinds of work.

You have probably observed that electricity passes through some materials and not through others. As you know, it passes readily through the wires in your house. From them it goes through other wires to your radio, toaster, vacuum sweeper, and so on. These wires are made of copper. Because copper allows electricity to pass through it easily, it is called a *conductor*. Most metals are good conductors of electricity, silver being the best; but silver is too expensive to use for wiring houses. Materials such as rubber, glass, bakelite, and wood ordinarily cannot conduct currents of electricity. They are called *insulators* and are used to prevent electricity from traveling where it is not wanted. All the electrical wiring in your home is covered with insulation so that the electricity will not be conducted to places where it may do damage.

How do metals conduct electricity? To explain how metals conduct electricity, we must examine the atomic structure of a conductor. A piece of copper wire, for example, is composed of billions and billions of atoms of copper. Most copper atoms have 29 electrons in the various orbits surrounding the nucleus. Some of these electrons travel in orbits so far from the nucleus that they seem to be held very loosely by it. Then, too, the atoms are packed so close together that the outermost electrons of one atom tend to be pulled toward the nucleus of a neighboring atom. Thus in a piece of copper wire a great many electrons are so nearly free that they can easily be



Placing a magnet near a compass, as shown at left, causes the pointer to turn as indicated by the arrows. Electricity flowing from the outside pole (—) to the center pole (+) through a conductor placed over a compass causes the pointer to turn as shown. Reversing the direction of the electricity will reverse the direction in which the pointer moves.

moved from atom to atom. These electrons are called *free electrons.* It is the numerous free electrons that make a substance like copper a good conductor. Under certain conditions, large numbers of free electrons are caused to move from one atom to another. This movement of electrons is an electric current.

The action along a wire conducting electricity may be compared to that in a long tube filled with marbles. The tube represents the wire and the marbles the free electrons. If an additional marble is forced into one end of the tube, it pushes the marbles all along the tube, forcing one marble out at the opposite end. Although each marble moves only a short distance, all the marbles in the tube are set in motion almost instantly. In a similar manner, when electrons are forced to move in one part of a conductor, all the electrons throughout the conductor begin to move. Thus, like the marbles, each electron travels only a short distance. In fact it is estimated that in ordinary electrical circuits each individual electron travels along the wire about 0.003 of an inch per second. Thus, if the powerhouse that supplies electricity to your home were one mile away, electrons leaving it on the first of January would not arrive at your home until about the third week in August. But remember that as a few electrons are moved in the wire, the electrons all along the wire begin to move instantly. Thus you actually get a wave of electron motion, or an electric current, from the powerhouse in about one five-millionth of a second (or only slightly more time than it takes light to travel), even though each individual free electron moves forward slowly.

Electrons produce electric fields. To produce an electric field, a large number of electrons must be brought together at one place. This is what happens when an electric field is produced by rubbing a rubber rod with fur. To produce the electric field for a low-frequency radiant energy wave, a large number of electrons are brought together by being forced into a *capacitor,* which consists of two conductors separated by an insulator. A capacitor seems to store electrons as a storage reservoir stores water. Just as water is pumped into a reservoir for storage and released for use as needed, so electrons can be forced into a capacitor to be released later. While the electrons are stored in the capacitor, they create an electric field.

Electrons produce magnetic fields. If you place a wire over the needle of a compass and force a stream of electrons through it by connecting the wire to a battery, the compass needle will move. The needle will also move if you bring a magnet near it, as shown in the drawing on page 154. These observations support the belief that the motions of electrons produce a magnetic field. It is important to remember this generalization as you continue your study.

SOURCE OF RADIANT ENERGY

Producing low-frequency radiant energy. If electrons are made to flow into and out of a capacitor, first in one direction and then in the opposite direction, a low-frequency radiant energy wave may be produced. Electrons in motion create the required magnetic field, and electrons stored in the capacitor produce the required electric field. The rate at which the electrons change their direction of flow into and out of the capacitor determines the frequency of the radiant energy wave they produce.

A device to carry on the process described above is known as a *tuned circuit*. It is widely used by radio broadcasting stations to produce their radio waves. Although there are other ways of causing electrons to create radiant energy waves, the operation of the tuned circuit serves to illustrate how the electrons produce low-frequency radiant energy waves.

Producing high-frequency radiant energy. To get an idea of the way scientists think high-frequency radiant energy such as visible light and ultraviolet light is produced, we shall use the hydrogen atom as an illustration, because it is the simplest atom. The process in other atoms is essentially the same but far more complex than that of the hydrogen atom.

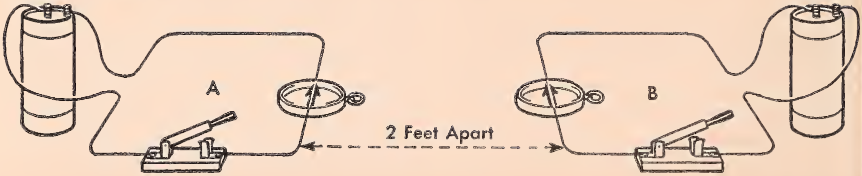
In its normal condition, the electron in the hydrogen atom appears to be in the orbit nearest the nucleus. Now if energy is added to the atom by some means, such as heating, the energy content of the atom is increased. Some of the additional energy is taken on by the electron. After the electron absorbs a certain amount of energy, it seems to have more than it can hold and still stay in its usual orbit, so it jumps into some other orbit farther from the nucleus. Atoms in which the electrons have jumped from inner orbits to those farther from the nucleus are called *excited atoms*. Occasionally, for some reason not yet understood, electrons in the outer orbits of excited atoms will fall back to inner orbits nearer the nucleus. Each time an electron falls from an outer to an inner orbit, the atom gives off a bundle of radiant energy (see page 151). The atom seems to give off the same amount of energy that was needed to cause the electron to jump into an outer orbit. These small bundles of radiant energy given off by the atom are called *quanta* (plural of *quantum*) of energy. It is these quanta of energy, given off from billions and billions of atoms, that are thought to be responsible for the particle behavior of radiant energy (see page 147).

Thus to produce higher frequency radiant energy, it is only necessary to add energy to the atoms until they become excited, after which their electrons start falling back from outer orbits into orbits nearer the nucleus. The type of radiant energy produced depends both upon the orbit from which the electron is coming and the orbit into which it jumps.

SUMMARY

The different types of radiant energy not only have some common characteristics but also a common source, the atom. Radiant energy is produced by the action of electrons in the atom. Whenever electrons are forced into and out of a capacitor in rapid succession, radiant energy of low frequency is produced. Whenever an atom absorbs sufficient energy so that electrons move into orbits farther out from the nucleus than they usually occupy, it is said to be an excited atom. When electrons in excited atoms fall back into inner orbits, radiant energy of higher frequency is produced. The type of high-frequency radiant energy produced is determined by the orbits from which and into which the electron jumps.

EXPERIMENT



The statements to be tested. 1. An electric current produces a magnetic field.

2. The direction of the magnetic field depends upon the direction of the electric current.

What you need. Two compasses; a bar magnet; some copper wire; two dry cells; two knife switches.

What to do. Connect the equipment as shown above, making the wire squares about 18″ on a side. Note the reversed connections of the dry cells. Now bring the north pole of the magnet near one compass and then the other, noting its effect on the pointers. Do the same with the south pole. Now close the switch briefly on circuit A and note the effect on *both* compasses. (Do not keep switch closed—the effect occurs at the moment of closing the switch.) Close switch at B and observe effect on both compasses.

Some basic assumptions. 1. A magnetic field will cause a compass pointer to move.

2. The direction in which the compass pointer moves indicates the direction in which the magnetic field is acting.

3. A dry cell will cause an electric current in a circuit.

4. The direction of the electric current is from the negative terminal through the conductor to the positive terminal of the dry cell.

Your answer. 1. How did you prove in this experiment that an electric current produces a magnetic field?

2. How did you prove in this experiment that the direction of the magnetic field depends upon the direction of the electric current?

3. What was the reason for using two sets of equipment and making observations upon both compasses?

4. What additional assumption would you have to make in order to say that all electric currents produce magnetic fields?

TEST YOURSELF

Select the ending which best completes each statement and write its letter on your answer sheet.

1. The nucleus of most atoms is made up of neutrons and (a) electrons; (b) protons; (c) molecules; (d) helium.
2. The parts of an atom are arranged very much like a (a) miniature solar system; (b) tiny molecule; (c) galaxy; (d) tuned circuit.
3. The parts of an atom that swing around its center are called (a) neutrons; (b) protons; (c) electrons; (d) nucleus.
4. A current of electricity is a flow of (a) protons; (b) atoms; (c) electrons; (d) bundles of radiant energy called quanta.
5. A substance that carries electricity readily is called (a) a conductor; (b) an insulator; (c) a capacitor; (d) a tuned circuit.

CHAPTER ACTIVITIES

REVIEW YOUR UNDERSTANDING

1. One important generalization developed in this chapter is: Certain characteristics are common to all types of radiant energy. On your answer sheet, write the letters of the statements below that support this generalization. **Do not write in this book.**

a. Insects are attracted by light.

b. Radiant energy can travel through empty space.

c. Radiant energy waves are electric and magnetic fields which travel through space at about 186,000 miles per second.

d. Magnetic fields affect iron filings.

2. Another important generalization developed in this chapter is: The atom is the source of radiant energy. On your answer sheet, write the letters of the statements below that support this generalization.

a. Under certain conditions when electrons fall from an outer orbit to an inner orbit visible light is produced.
b. Radiant energy can travel through space.
c. When electrons are caused to move back and forth in a circuit they may produce radio waves.
d. An excited atom may give off several different types of radiant energy.
e. Silver is a good conductor of an electric current.
f. Molecules of compounds are made up of atoms.

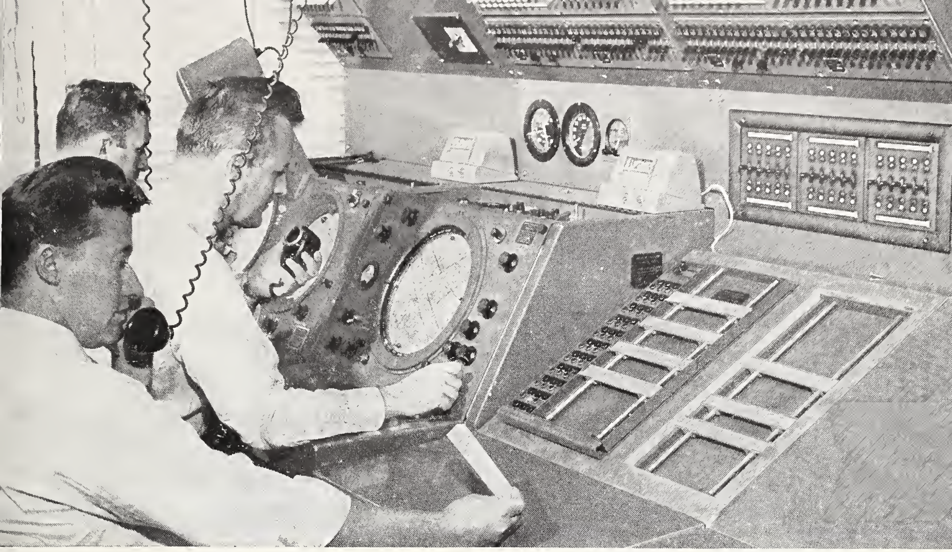
RECOGNIZE ASSUMPTIONS

1. The fact that the earth receives light from the sun has been used as evidence to support the generalization that radiant energy travels through space. On your answer sheet, write the letters of the statements below which would have to be accepted as assumptions to make this true.

a. Light travels in the same manner as other types of radiant energy.
b. Much of the space between the sun and earth is empty.
c. There are periods of daylight and darkness on the earth.
d. There is a sun.

2. It can be observed that when a magnet is placed under a glass plate covered with iron filings, the filings arrange themselves in a definite pattern. From this observation it may be concluded that a magnetic field caused this effect upon the iron filings. On your answer sheet, write the letters of the statements below which would have to be accepted as assumptions to make this conclusion true.

a. A magnetic field was produced by the magnet.
b. Magnets are made of iron.
c. A magnetic field acts through glass.
d. A magnetic field was the only force acting upon the iron filings.
e. Iron filings are different from other kinds of materials.



The Port of New York Authority

Using radiant energy to help an airplane land in bad weather. The operator in the airport views the approaching plane on a radar screen and tells the pilot every move to make in landing his plane.

chapter 9 USING RADIANT ENERGY

ALTHOUGH all the types of radiant energy have certain common characteristics, they differ widely from each other in many respects. The uses man makes of the various types of radiant energy depend upon their differences rather than their common characteristics. Radio waves, because they differ in wave length from the other types, are most suitable for wireless communication, although other types of radiant energy are sometimes used. Visible light is the only type that affects the eye and makes vision possible. The use of X-rays depends upon the fact that they have a different effect on materials than other types of radiant energy. This chapter will help you to understand how man controls the various types of radiant energy for some useful purposes.

PROBLEM 1. How do we use radio waves?

RADIO WAVES FOR COMMUNICATION

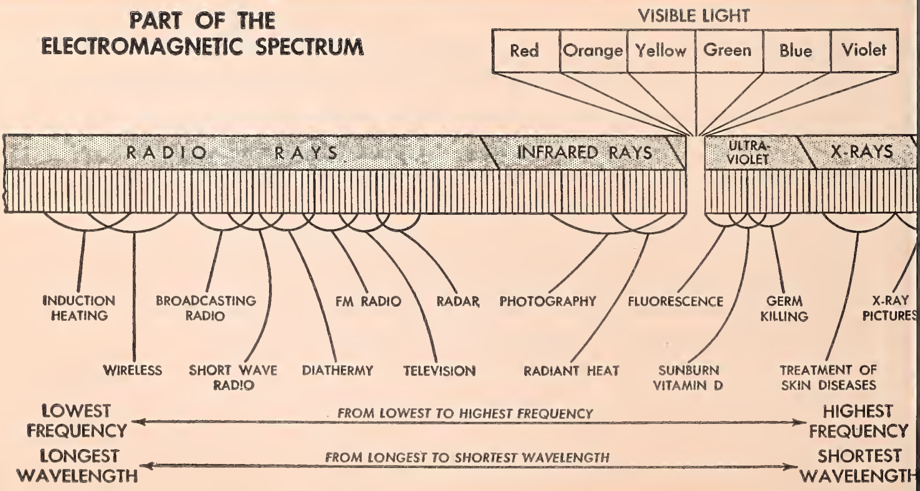
Purposes for which radio waves may be used. We have learned that types of radiant energy differ with respect to their frequencies and wave lengths. Radio waves have lower frequencies and longer wave lengths than other types of radiant energy. Their frequencies range from 10,000 c.p.s. to about 100,000 megacycles. Their respective wave lengths range from about 33,000 meters to about 0.00033 meter.

Because of the value of radio waves for communication and other purposes, there has been great demand for their use. In order to decrease conflicts and confusion in the use of radio waves by different individuals and agencies, some control is necessary. The Federal Communications Commission, commonly referred to as the FCC, controls and supervises the use of radio waves in the United States. It assigns certain radio waves for definite uses and issues licenses for such uses.

Radio waves are used for both long- and short-wave broadcasting and in television. They are also used for telegraph and telephone communication where it is impractical to use wires. This type of radiant energy can also be used to heat materials and to produce an artificial fever in the treatment of certain diseases. Radar, which has proved so valuable in the safe operation of airplanes, makes use of certain frequencies of radio waves.

Development of radio. Perhaps you have heard static in your radio when you were running the vacuum cleaner or when someone was using an electric razor. Any electrical device which produces sparks causes static in most radios. Lightning, which is a huge natural electric spark, may cause so much static that the program to which the radio is tuned cannot be heard at all.

A part of the electromagnetic spectrum showing the frequency and wavelength relationship of different forms of radiant energy and their uses. Gamma rays, given off by radium and used in research and treatment of diseases, and cosmic rays, still somewhat of a mystery, would appear to the right of X-rays on the spectrum.



The first radio waves to be broadcast were produced by a series of electric sparks. Although these waves could be received at some distance from the place where they were produced, voice and music could not be broadcast with them. Instead, they were used to broadcast messages by the Morse Code. In this code, letters of the alphabet are represented by short and long sounds called *dots* and *dashes*. Spark wireless, as this kind of broadcasting was called, did not prove satisfactory for several reasons. It could be used only for code; the waves sent out from various stations interfered with each other; and it could be received for only short distances.

The limitations of spark wireless were overcome by the invention of tubes similar to those used in modern radios. These tubes have made it possible to control the flow of electrons so that radio waves are produced. The waves can be used to broadcast voice and music. These tubes have also made it possible to build radio receivers that can detect radio waves sent from great distances.

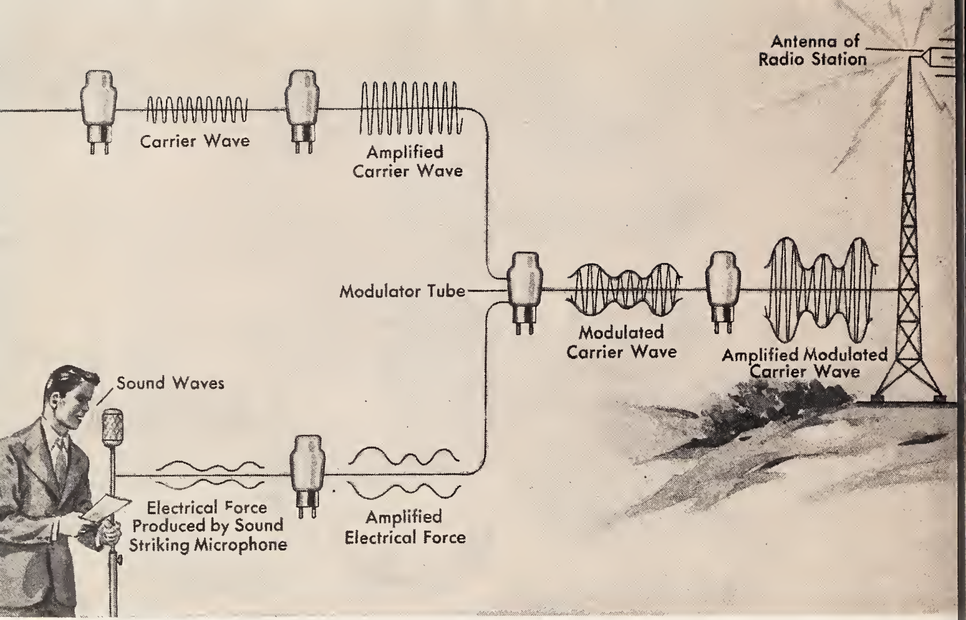
Since the first radio tube was invented, scientists have developed a great family of similar tubes now numbering more than a thousand types. They have one thing in common—they all control the flow of electrons. They are therefore generally called *electron tubes*. The science dealing with these tubes and their applications is known as *electronics*. Thus when you study radio, television, or other devices using electron tubes, you are studying electronics.

Broadcasting radio waves. The station from which radio programs are broadcast is called a *transmitter*. The essential steps in radio broadcasting are shown on pages 162 and 163. Only a general explanation is included in this book. More complete information will be found in the references listed at the end of this unit. In the drawing you will see how the *carrier wave* (so called because its magnetic and electric fields vary according to the sounds in speech and music, thus "carrying" speech and music from the station to the listener) is increased in power, or *amplified;* then it is sent to a large tower, the *antenna,* from which it escapes into space. As the drawing shows, the performers in the *studio* direct their speech or music toward a *microphone,* where the sound causes the microphone to develop an electrical force.

This force is amplified and by a process called *modulation* mixed with the carrier wave being developed at the radio station. The carrier wave is then amplified again, directed to the antenna, and escapes into space. Since it is a radiant energy wave, it travels about 186,000 miles per second; thus speech and music can encircle the world in a fraction of a second.

Receiving radio waves. When radio waves strike the antenna of a radio receiver, they produce similar waves in the antenna which are amplified by an electron tube. Other tubes then separate the electrical force produced by the program at the studio from the carrier wave. The electrical forces are amplified and are finally led to a loudspeaker, where they produce sound. Thus the program produced in the studio is reproduced in your home.

The earlier radios used a long, single wire high above the ground for an antenna in order to get satisfactory reception. As improvements were made in radio receiving sets, it became possible



In radio broadcasting, the carrier wave is produced by using radio tubes and tuned circuits. The microphone develops electrical forces that change as sounds directed toward it change. Electrical forces from the microphone are mixed with the carrier wave in the modulator tube. It is this modulated carrier wave that is transmitted from the antenna of the broadcasting station.

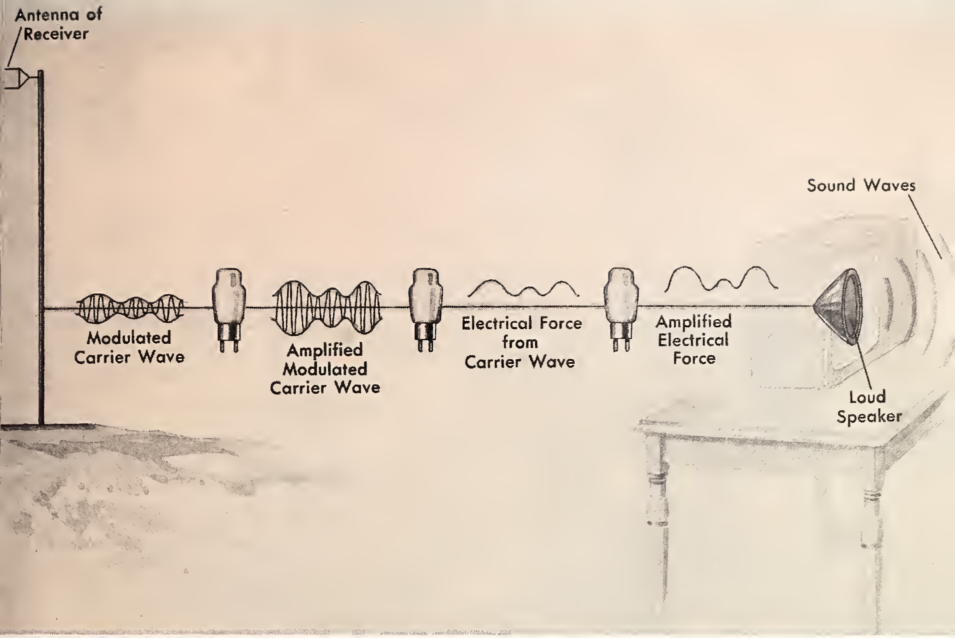
to get satisfactory reception with a much smaller antenna. Many modern radio receivers have the antenna built into the cabinet. They can operate with a small antenna because they amplify the waves produced in the antenna as much as 500,000 times before they reach the loudspeaker.

Selecting a good radio receiver. A radio receiver should be selected on the basis of its (1) *sensitivity,* (2) *selectivity,* (3) *fidelity,* and (4) *mechanical construction.*

Sensitivity is a radio's ability to receive programs from a weak radio wave. High sensitivity is important if you wish to listen to stations located a long distance from your receiver or to weak stations.

Selectivity is the ability of a radio to separate one station from another. As regular broadcasting is now conducted, if you want the best tone quality in a radio, you will have to be satisfied with one that is not highly selective. On such a radio you may not be able to tune in so many stations, but the tone will be better.

In a perfect radio, a program would be reproduced so that it sounded as natural as if you were in the studio from which it was coming. The measure of a radio's ability to reproduce programs naturally is called its fidelity. Most console radios overemphasize the low tones and are lacking in the high tones. The reverse is usually true with the small table models.

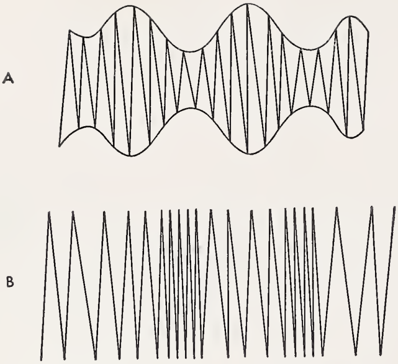

Antenna of Receiver
Modulated Carrier Wave
Amplified Modulated Carrier Wave
Electrical Force from Carrier Wave
Amplified Electrical Force
Sound Waves
Loud Speaker

In radio receiving, the broadcast radio wave strikes the antenna of the receiver and produces a similar wave in it. The wave is then amplified by an electric tube, and other tubes separate the electrical force from the carrier wave. Since this electrical force was produced by sounds in the broadcasting studio, it can be used in the loud speaker to reproduce those sounds.

A good radio is constructed so that the various parts are not crowded. If the parts are crowded, the radio may become overheated and may also be difficult to repair. All the parts should be firmly fastened, and the cabinet should be solidly constructed. Complicated tuning dials tend to increase the possibilities of trouble.

AM and FM broadcasting. There are two types of radio broadcasting: AM and FM. AM is an abbreviation for *amplitude modulation.* All radio stations broadcasting with frequencies from 550 to 1500 kilocycles use amplitude modulation (see page 161). In AM the sounds made in the studio change the amplitude, or strength, of the radio wave. The changes of amplitude make your radio reproduce the sounds being broadcast from the radio station.

Every radio that receives AM, however, also receives static from electric sparks. Static has been a serious problem. In attempting to overcome or remove it, Major E. H. Armstrong, an American scientist, invented an entirely new type of broadcasting called *frequency modulation* or FM. In FM broadcasting the sounds in the studio cause changes in the frequency of the carrier wave rather than in its amplitude. Since electric sparks do not affect the frequency of the radio wave, FM can provide static-free reception. FM broadcasting is planned so that its fidelity is high. Radio sets are specially



A. AM wave **B. FM wave.**

designed to receive FM broadcasts; for best results a special antenna is required.

The sound accompanying television programs is broadcast by FM. The television receiver, therefore, contains an FM receiver which reproduces the sound broadcast from the television studio. The manner in which the television picture is broadcast and received will be described in Problem 3 on pages 182-185 of this unit.

RADIO WAVES FOR HEAT

Practical uses of heating effects. During World War II many airplanes were constructed from plywood, made by cementing several thin layers of wood together. Plywood must be heated while it is being made. At the beginning of the war, this was done by applying heat to the top and bottom of the wood sheet. But this process was slow, and plywood could not be produced as fast as it was needed.

Radio waves came to the rescue. The thin layers of wood were placed between two large metal plates, and low-frequency radio waves were passed through them. The wood was heated throughout almost instantly, thus making it possible to produce plywood more rapidly than by the older method.

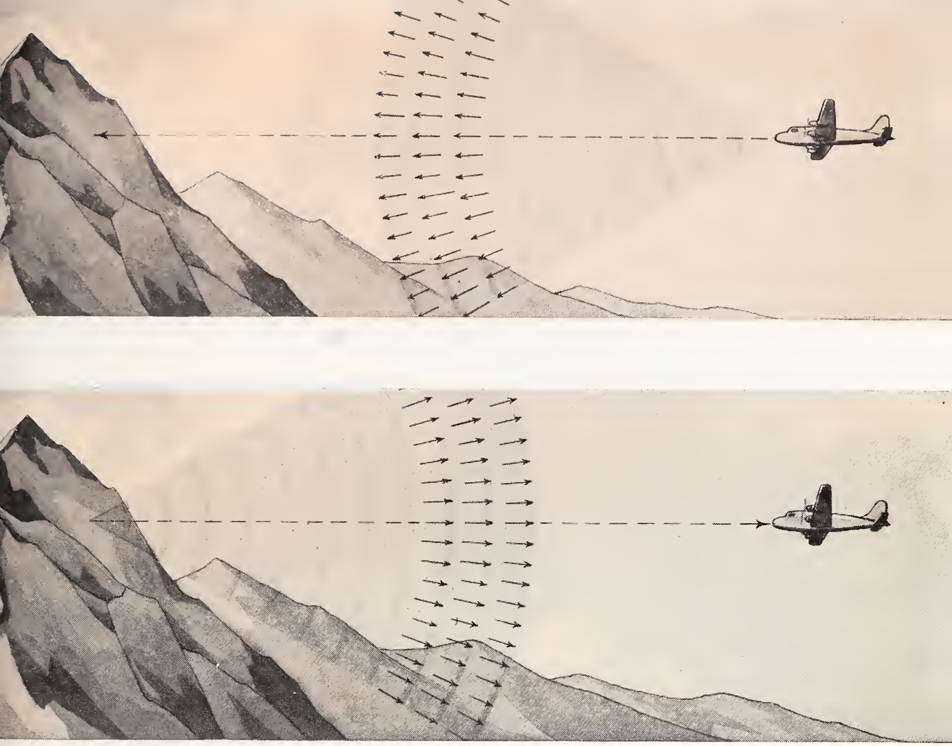
Low-frequency radio waves are used for heating many different kinds of materials. Metals can be heated to any depth or melted as desired. With older methods of heating, metal sheets could be covered with tin at the rate of 200 feet per minute. By heating with radio waves, they can be covered at the rate of 1,000 feet per minute. The heat required in the manufacture of articles of plastic, such as small radio cabinets, dishes, and combs, can be conveniently produced with radio waves. Food can be cooked with radio waves in a much shorter time than by the usual methods, for heat is produced throughout the food although the oven itself is cold.

Medical uses. Radio waves are often used to produce heat in the human body in the treatment of body ailments. A large rubber-covered wire is placed around the part of the body where heat is wanted. Radio waves of the proper frequency are then passed through the cable, producing heat where the body is surrounded by the cable. It is possible thus to increase the temperature of any part of the body by using radio waves.

RADIO WAVES FOR NAVIGATION

Radar. The name *radar,* a contraction of the phrase "Radio Detection And Ranging," is given to any device that discovers and determines the position of objects by means of radio waves.

With radar, ships have been discovered, tracked, fired upon, and sunk without having been seen. Targets have been located and bombed by planes through an overcast of heavy clouds.



The arrows represent pulses of radiant energy. By measuring the few millionths of a second required for the pulses to reach the mountain and return, and knowing their speed, the distance to the mountain can be obtained.

Radar makes it possible for a captain to pilot his ship safely through dangerous waters in deepest fog. In an airplane equipped with radar the pilot has before him, in darkness or in fog, a view of everything around him including other planes. With radar instruments in operation, accidents in the air and at sea are very much less likely to occur.

How radar operates. In a radar system, short *pulses* of high-frequency radio waves, each pulse about a millionth of a second long, are sent out through space at the rate of a few thousand each second. Thus, there is a pause for a few thousandths of a second between pulses. If the radio waves strike an object (see above), some of them return to the place from which they were sent. During the pause between pulses, a radar receiver detects the waves as they return from the object. If the radar antenna is slowly rotated, a picture like that on page 166 can be obtained with special equipment in the radar receiver.

Radar at work. Radar is invaluable in an emergency at sea. On one occasion a ship 200 miles at sea reported by radio that one of its seamen had been taken seriously ill and needed to be hospitalized immediately. Though there was a heavy fog at the time, a

Coast Guard pilot easily located the ship by radar, landed beside it, and flew the sailor to the hospital for the treatment he urgently needed.

Radar is almost a necessity to airplanes during fogs. At an airport the fog is so dense that the runways can not be seen. Planes are due to land at any moment. With their radar equipment, the men in the control tower can tell exactly where every plane in the vicinity is, at what distance from the airport, and at what altitude each plane is flying. By radio communication with the pilots the planes are "talked in" to a safe landing, even though the airport is invisible to the pilots because of the fog.

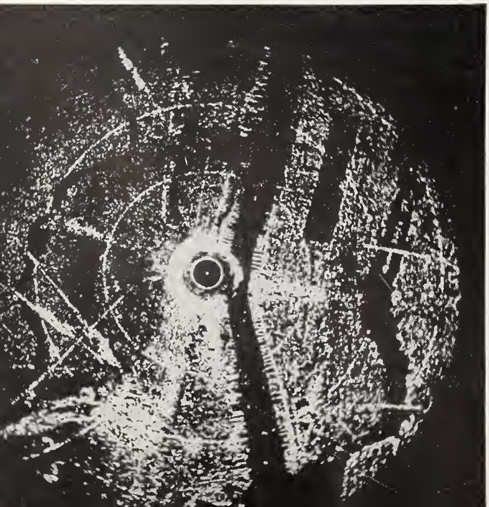
Radar also has other uses. It is making motoring safer, as shown on page 167, and it has made it possible for scientists to know they have reached the moon with radio waves, thus aiding them in their study of the heavens.

Loran and Shoran. The term *loran* is made up of the first letters of the phrase "LOng RAnge Navigation." Through its use a navigator can determine the position of his ship or plane in any kind of weather. Loran is operated by radio waves sent to the ship from two radio stations, the exact locations of which are known to the navigator. By computing the difference between the time he receives one signal and the time he receives the other, he can determine the position of his ship.

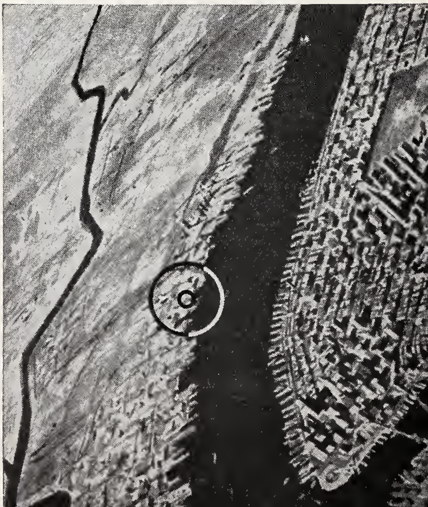
Another type of radio navigation is known as *shoran*. The name comes from the first letters of the phrase "SHOrt RAnge Navigation." An airplane or ship using shoran can locate any spot on the earth within ten feet of its exact position. Shoran is operated by two radio stations which maintain radio contact with an airplane as it flies toward its destination. A recording device in the radio receiver of the airplane indicates when the plane has arrived at its destination.

At left is a photograph of parts of New York City and cities in New Jersey as seen on a radar screen. At right is an air photograph, with the identical center marked, of the same area.

Massachusetts Institute of Technology



The Port of New York Authority



SUMMARY

Radio waves are used in many different ways. They can be used to broadcast sound or pictures through space. In radio broadcasting, radio waves are modulated by sound sent out through space and used by the receiver to reproduce the sound produced in the studio.

Radio waves of certain frequencies are used as a convenient method of heating many materials. Radar depends upon the fact that radio waves of certain frequencies return from objects they strike at a known speed, thus making it possible to locate and determine the distance of the object from any point. Loran and shoran are methods of navigation in which radio waves are used to locate the positions of ships or airplanes.

The use of radio waves for these many purposes has been made possible through the development and use of electron tubes.

Connecticut State Police Photo

A patrolman on a bridge uses special radar equipment to measure the speed of cars on the parkway below. He radio-telephones the license of a speeding car to a patrolman ahead, who stops the driver.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The use of radio waves in the United States is controlled and supervised by (a) The National Association of Broadcasters; (b) The Interstate Commerce Commission; (c) The Federal Communications Commission; (d) American Association for the Advancement of Science.
2. When the strength of a radio wave is increased by use of electron tubes, the wave is (a) amplified; (b) modulated; (c) detected; (d) decreased.
3. The ability of a radio to reproduce programs naturally is called (a) its fidelity; (b) its sensitivity; (c) its selectivity; (d) its amplitude modulation.
4. When short pulses of radio waves are used to determine the location and distance of an object from some point, the system is known as (a) radar; (b) loran; (c) shoran; (d) electronics.
5. A radio broadcasting system in which speech and music change the frequency of the wave is known as (a) AM; (b) PM; (c) FM; (d) FCC.

PROBLEM 2. How do we use infrared radiant energy?

INFRARED RAYS

Characteristics. As you can see in the chart on page 160, *infrared* rays have shorter wave lengths and higher frequencies than radio waves. Because of their frequencies and wave lengths, infrared rays have certain characteristics important to us. Probably their most important characteristic is their ability to produce heat in any object that absorbs them. It is the infrared rays from the sun that make you feel warm when you stand in the sunshine. The warmth from a fireplace or an open fire, too, is due largely to these rays.

Infrared rays penetrate the surface of the skin and produce a warming sensation. They are often used in the treatment of bruises and sprains because they generate heat in the sore muscles.

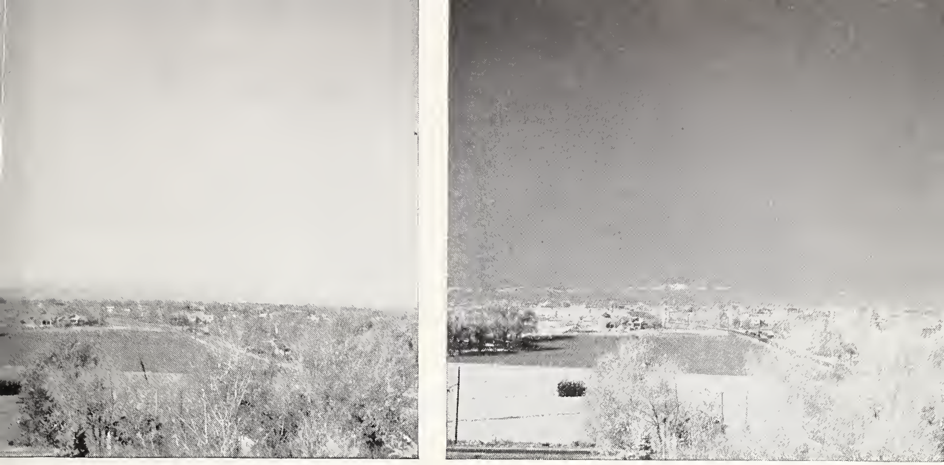
Sources of infrared rays. Our principal source of infrared rays is the sun. Even on a cloudy day some infrared rays from the sun reach the earth. Any material that is heated gives off infrared rays in usable amounts. A fireplace, a hot stove, an electric toaster, and a hot oven are examples. The frequency of the rays produced depends upon the temperature of the substance.

Most electric lamps produce infrared rays, but some are especially constructed to produce a larger amount of infrared rays that can be concentrated on the object to be heated. The type of infrared lamp that has a clear-glass bulb with a metal reflector inside it gives off a considerable amount of visible light. A lamp that has a ruby-red glass bulb reduces the amount of visible light.

Infrared rays at work. The most common use of infrared rays is to produce warmth for human comfort. Some buildings are heated entirely by infrared rays of radiant energy. Heating

MORSE CODES

International Morse		American Morse	
A ● ▬	N ▬ ●	A ● ▬	N ▬ ●
B ▬ ● ● ●	O ▬ ▬ ▬	B ▬ ● ● ●	O ● ●
C ▬ ● ▬ ●	P ● ▬ ▬ ●	C ● ● ●	P ● ● ● ● ●
D ▬ ● ●	Q ▬ ▬ ● ▬	D ▬ ● ●	Q ● ● ▬ ●
E ●	R ● ▬ ●	E ●	R ● ● ●
F ● ● ▬ ●	S ● ● ●	F ● ▬ ●	S ● ● ●
G ▬ ▬ ●	T ▬	G ▬ ▬ ●	T ▬
H ● ● ● ●	U ● ● ▬	H ● ● ● ●	U ● ● ▬
I ● ●	V ● ● ● ▬	I ● ●	V ● ● ● ▬
J ● ▬ ▬ ▬	W ● ▬ ▬	J ▬ ● ▬ ●	W ● ▬ ▬
K ▬ ● ▬	X ▬ ● ● ▬	K ▬ ● ▬	X ● ▬ ● ●
L ● ▬ ● ●	Y ▬ ● ▬ ▬	L ⸺	Y ● ● ● ●
M ▬ ▬	Z ▬ ▬ ● ●	M ▬ ▬	Z ● ● ● ●



F. L. Herman

The picture at the left was taken on ordinary film, that on the right on film sensitive to infrared rays. Note how much more clearly the snow-capped mountains on the horizon 50 miles away stand out in the picture taken with infrared.

buildings in this manner will be discussed in greater detail in Unit 6.

Infrared rays are used in many types of industry. During World War II, for example, when the urgent demand for jeeps made it necessary to produce them very rapidly, infrared rays were used to hasten the drying of the paint. The jeeps were passed slowly through a long tunnel lined with infrared lamps, and the infrared rays dried the paint in nine minutes. By other methods it had taken forty-five minutes for the paint to dry. During cold weather, infrared generators are used in citrus fruit groves. The infrared rays, traveling from the generator through the cold air, produce heat in the fruit. The fruit is thus kept from freezing even though the temperature of the surrounding air is below the freezing point. A single infrared generator will protect as much as an acre of fruit. (See color photo, facing page 504.)

Films sensitive to infrared rays are used in photography. They can take pictures in total darkness and also at long distances through the atmosphere. By comparing the two pictures above, you can see how much more effective infrared rays are than visible light rays for this purpose.

SUMMARY

Infrared rays are a type of invisible radiant energy that causes materials which absorb them to become heated. Although the sun is our principal source of infrared rays, any heated material produces them. The rays are widely used in industry because of their heating effects. Waves of infrared radiant energy are longer than those of visible light and are less affected by the atmosphere. They can therefore be used in photography when it is important to get clear pictures of distant objects.

TEST YOURSELF

Select the word which best completes each statement and write it in the proper place on your answer sheet.

Do not write in this book.

1. Infrared rays have a (higher) (lower) frequency than radio waves.
2. When infrared rays warm an object, the heat is (carried) (produced) by the rays.
3. Our principal source of infrared rays is (the sun) (heat lamps).
4. Infrared rays are affected less than visible light as they pass through (empty space) (the atmosphere).
5. Infrared rays can be used to take pictures in (partial) (total) darkness.

PROBLEM 3. How do we use light rays?

SOURCES OF LIGHT

Nature of light. When a thin beam of sunlight enters a darkened room, its path can be followed only if there are small particles, such as those of dust or smoke, in the air (see picture, page 143). If the air were free of all particles, the light could not be seen. However, if the beam of light strikes a sheet of white paper, a band of white is seen. If a *prism* is placed properly in the beam of sunlight, the band of white on the paper changes to a band of color. All the colors of the rainbow are present. Finally when a second glass prism is placed after the first, the colored band again becomes white (see color drawings, facing page 216). Thus

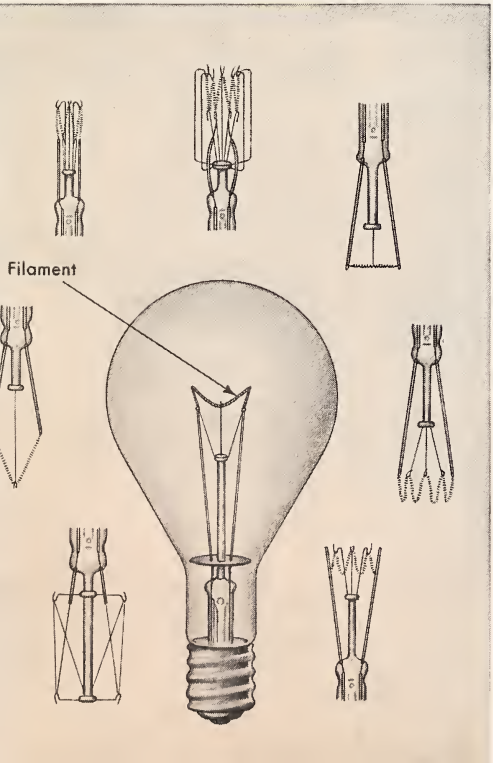
if sunlight can be spread out by a prism to produce the colors of the rainbow,

if the spread-out sunlight which produces color can be narrowed back to sunlight by a prism,

then, sunlight must have in it the light which produces the colors of the rainbow.

This idea, so readily accepted today, was startling when first proposed by Sir Isaac Newton in 1672. Sunlight, then, must not be a single thing. It must contain a variety of components some of which, when spread apart, can cause color to be seen.

The ordinary incandescent electric lamp is a filament of tungsten wire mounted inside a glass bulb. The bulb is filled with a mixture of nitrogen and argon gas rather than air. This prevents oxidation of the filament.



Visible light. Sunlight has a band of radiant energy called *visible light* in it. As shown facing page 216, visible light occupies only a tiny part of the total spectrum (see page 160) of radiant energy. Being radiant energy, it travels about 186,000 miles per second, it exhibits the wave characteristics of frequency, amplitude, and wave length; yet at times it seems to be made of particles. These particles are called *photons* and seem to be the bundles of energy referred to on page 155. Visible light is radiant energy with frequencies from 485 trillion to 870 trillion cycles per second. The wave lengths of light are so extremely short that scientists have adopted tiny measuring units for them. One commonly used unit is the *millimicron* ($M\mu$) which is one billionth (1/1,000,000,000) of a meter.[1] In these terms, visible light consists of radiant energy with wave lengths from about 400 to 700 millimicrons ($M\mu$) (see page 146).

Natural light and artificial light. Light that comes to us directly from the sun and from distant stars is natural light. However, since we receive very little light from distant stars, the sun is our most important source of natural light. Even light from the moon is reflected from the sun.

Light not obtained directly from the sun is called *artificial light*. For many centuries the only way man could produce artificial light was to burn substances such as oil, candles, and gas which contain carbon. When carbon atoms are heated, they produce a yellowish-red light.

It is no longer necessary to burn materials in order to produce light. It was discovered that when electricity is passed through a wire of *tungsten* (a metallic element), the wire becomes extremely hot and gives off light. A substance that gives off light when it is heated white-hot is said to be *incandescent*. Electric lamps are therefore often called incandescent lamps.

Both flames and incandescent wires depend upon heat to produce light. But producing light by the use of heat is inefficient. It is estimated that of the electricity used by an incandescent lamp, less than 10 per cent actually produces light, the rest being used to produce the required heat.

The *fluorescent* lamp is more efficient than the incandescent lamp, since almost 20 per cent of the electricity required to operate it is used in producing light. The drawing on page 172 shows how the fluorescent lamp produces light.

Light comes from excited atoms. The sources of light just described depend either upon high temperatures or upon a stream of electrons. But neither the heat nor the stream of electrons really produces the light. They merely supply the energy needed to cause the atoms of some material to produce light, as discussed on page 155.

Why objects are visible. Many attempts have been made to explain why objects can be seen. Aristotle, an early Greek scientist, believed that light was sent out from the eye and that when it fell upon an object, that object could be seen. For many centuries Aristotle's explanation of visibility was believed to be correct. But about 1670 Sir Isaac Newton, an English scientist, developed an entirely different theory of visibility. He suggested that when an object such as a lamp gives light, the light floods all the space around the lamp. Some of this light falls upon objects around the lamp and is *reflected,* or returned to the eye. It is the reflected light that makes the object visible.

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[1] Another is the *Angstrom* (A°) which is even shorter, being 1/10 of a millimicron. Thus 380 $M\mu$ would equal 3800 A°.

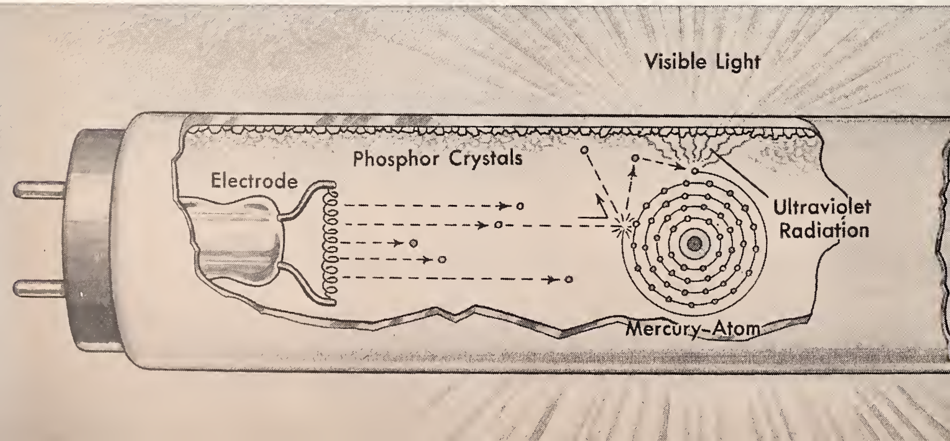
Scientists today explain visibility in about the same way Sir Isaac Newton explained it. The sun, a lighted electric lamp, and a neon sign are sources of light and can be seen because of the light that comes from them directly to the eye. An object flooded with light from a source of light is said to be *illuminated.* Illuminated objects are visible because they reflect light to our eyes.

Reflection from mirrors. Any smooth surface which reflects light so that an image can be formed is known as a *mirror.* A mirror can be made by coating one side of a piece of glass with silver or aluminum. Highly polished metal and a pool of quiet water are also mirrors.

The image of yourself which you see in a mirror is formed when light reflected from different parts of your body strikes the mirror and is in turn reflected to your eye. To form an image of your body, however, the rays of light must be reflected from the mirror in the same pattern as they were received by it. Such a reflection is called a *regular reflection.* The top drawing on page 173 will help you to understand how regular reflection from a mirror takes place. The image seems to come from an object placed as far behind the mirror as the real object is in front of it, and it appears to be reversed. The crosspiece of the L is not at the bottom but at the top. Your own image in the mirror is also reversed (although it is not so easy to realize it) because the mirror has reflected or changed the direction in which the light rays are traveling.

Most of the mirrors we use are flat, or plane, mirrors. In such mirrors the image appears the same size as the object. Some mirrors, however, have

In a fluorescent lamp, high-speed electrons given off by the electrode hit electrons in atoms of mercury vapor within the tube, knocking the electrons into outer orbits. When these electrons fall back into inner orbits, as shown by the arrow, ultraviolet radiation is given off. When ultraviolet rays strike atoms of phosphor crystals lining the tube, a similar atomic action occurs and visible light is given off.



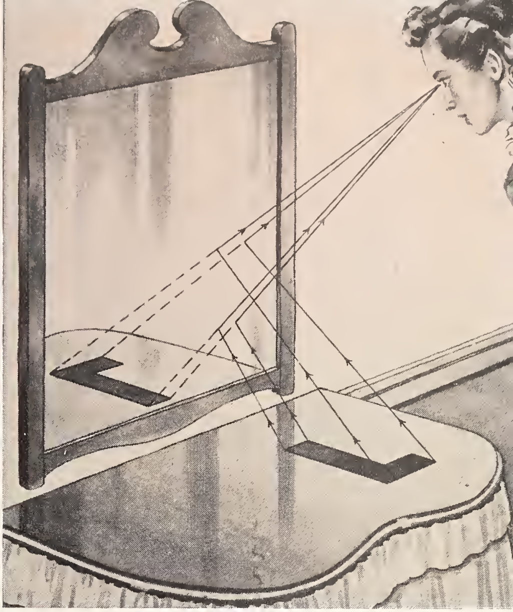
surfaces which curve inward or outward. If the light strikes a mirror that is curved inward, the image is often much larger than the object when the object is close to the mirror. Such mirrors are used to enlarge the image of the face for shaving or applying cosmetics. If, on the other hand, light strikes a mirror that curves outward at the center, the image formed is smaller than the object. Mirrors of this type are often used on automobiles and trucks because, though images are smaller than the objects, the driver can see a larger part of the roadway behind him.

Reflection of light from uneven surfaces. The paper in this book appears to be smooth, but if you examine it under a microscope you will see that it is quite rough. When rays of light strike such a rough or uneven surface they are not reflected as they are from a mirror. Their reflection is said to be *diffuse*. The drawing, lower right, will help you to understand why images are not formed by light reflected from an uneven surface.

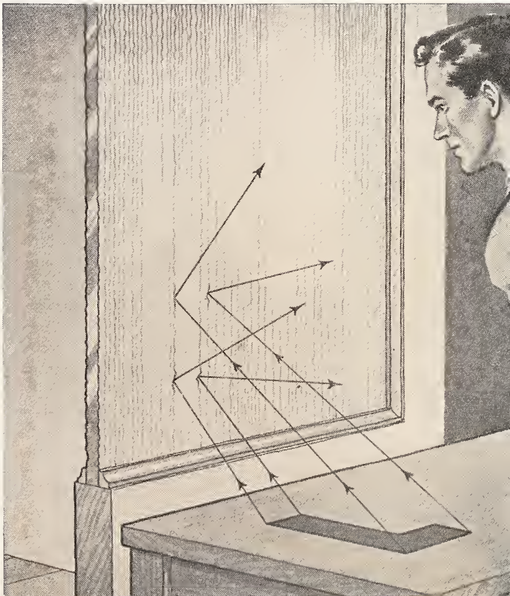
Refraction of light. If a pencil is placed in a glass of water, as you can easily see, it appears to be broken at the water line.

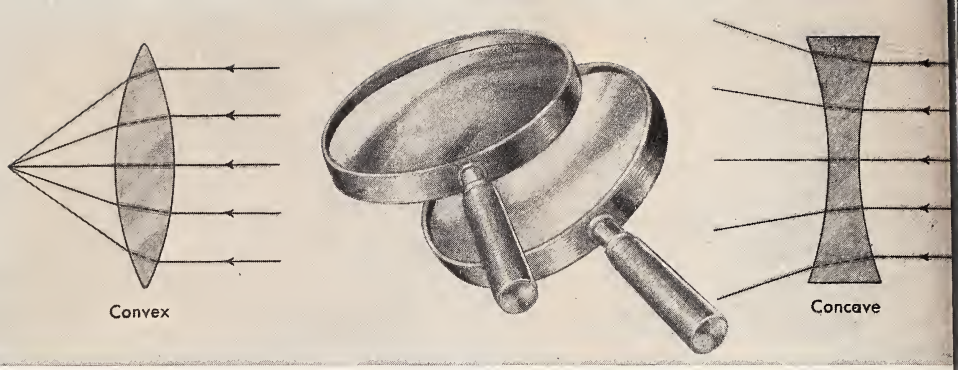
This is explained by the fact that the light rays coming from the pencil to the eye are bent as they leave the water, because the speed at which they travel is changed. Such bending of light rays is called *refraction*.

If the surface of a lens is curved so that it is thicker through the center than at the edges, the lens is *convex;* if it is thicker at the edges, the lens is *concave*. Because of its curved surface, most of the light passing through a lens is refracted, as shown in the drawing on page 174. Lenses are used in eyeglasses, field glasses, and telescopes.



The upside-down image of the L in the mirror is caused by the reflection of light rays from the mirror to the girl's eyes, in the pattern of the solid lines. The dotted lines indicate the position of the L in the mirror. Light rays from the figure L are reflected in an irregular pattern on the rough surface below, so that they do not form an image. Such reflections from rough surfaces are said to be diffuse.





The convex lens is shaped to bend light by refraction so that the light which falls on the lens is directed through one point. The concave lens is shaped so that it spreads the light rather than bringing it through a point. Both kinds of lenses can be used in hand-glasses.

THE EYE

How the eye works. To understand how the eye functions, let us see how images of objects can be formed without using mirrors. One simple way to produce an image is to use a pinhole camera. You will note on page 176 that light rays from the top of the window travel in a straight line through the hole and form an image on the lower part of the screen in the camera, and that light rays from the lower part of the window travel through the hole and form an image on the upper part of the screen. Thus the image on the screen is upside down, or *inverted.*

If a convex lens is used in place of a pinhole, a much clearer inverted image can be formed. An image that is sharp and clear is said to be *in focus.* A convex lens with more curve out from the center will focus an image closer to the lens than one of the same size with less curve. If the same lens is focused on a near and a far object, the image of the near object is formed farther from the lens than that of the far object.

In the eye (see diagram page 175), the *retina* corresponds to the screen in the camera. The distance between the retina and the lens is always the same. Therefore, to bring both near and far objects into sharp focus on the retina, the amount of curve in the lens must be changed.

When the eyes are focused on a near object, tiny muscles cause the lens to become more convex. It is held in this position as long as one looks at the near object. When the eyes are focused on a distant object, the muscles allow the lens to become less convex. The process of focusing images on the retina is called *accommodation.*

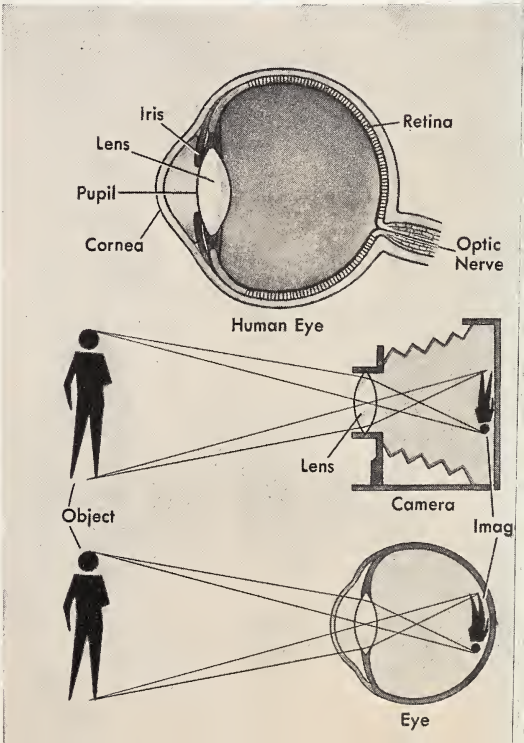
The retina is an extremely complex film covering the greater part of the inside surface of the eyeball. It contains some 7 million separate nerve endings, called *rods* and *cones,* which react to light falling on them. The rods are primarily sensitive to changes in the strength of light, while the cones are primarily sensitive to color. The rods and cones are not evenly distributed throughout the retina. Near the center of the retina, where the image is focused, there are only cones. There are about 34,000 cones in an area only this large ▪ (.5mm on each side)! Vision, for both color and detail, is best when the image falls on this area, called the *fovea*. The rest of the retina has a mixture of rods and cones with the cones steadily decreasing in number away from the center until only rods are found at the outer edges of the retina. There is a separate nerve fiber for each rod and cone near the central part of the retina, but there is only one for groups of nerve endings nearer the edge. As a result of this grouping, some one million, rather than 7 million, separate nerve fibers combine to make up the *optic nerve* for each eye. The optic nerve branches before it reaches the brain so that the nerve fibers from the left half of each eye (divided up and down through the center) connect to one side of the brain, while those from the right half connect to the other side of the brain.

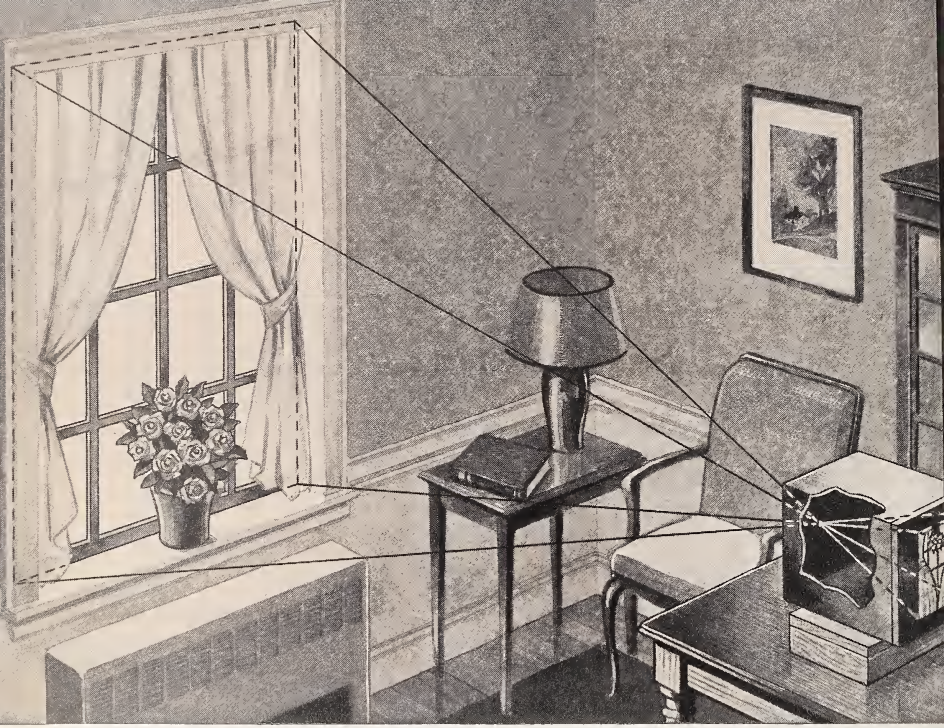
Vision. When the inverted image of an object falls on the retina, each rod and cone sends a series of nerve impulses to the brain. Several million of these impulses go to the brain each second and are somehow translated into vision. Vision is a mental action and does not take place in the eyes. For this reason brain injuries may affect vision even though the eyes are perfect.

While looking straight ahead, hold some small colored object at arm's length to your right and far enough behind you so that you can't see it. Now, still looking straight ahead, bring it forward until you can just see it. It will appear as an indistinct, black or gray object. Move it up and down. You can see the movement clearly. Now move the object forward until you can see color. Although you are aware of color and may be able to tell which colors are present, the details of the object are still not clearly seen. Keep moving the object forward until you can see its details clearly. Not until the object is directly in front of you, can you see it in detail.

The reasons for the above characteristic of vision can be found in the makeup of the eye. The image of an object just inside the field of vision falls near the outer edge of the retina. Since, in that area, there are only rods and relatively few nerves from them, objects are indistinct and have no color, but their movement is readily seen because movement of the object changes the strength of the light falling on the

Parts of the human eye are shown in the upper diagram. The eyeball keeps its spherical shape because it is filled with a transparent jelly-like material. The formation of images in a camera and the eye are compared in lower diagrams.





A simple pinhole camera. The back of the camera is made of translucent material such as tissue paper or frosted glass. The lines indicate the path of light from the corners of the window to the image. Light from every other point on the window travels to its appropriate point on the image.

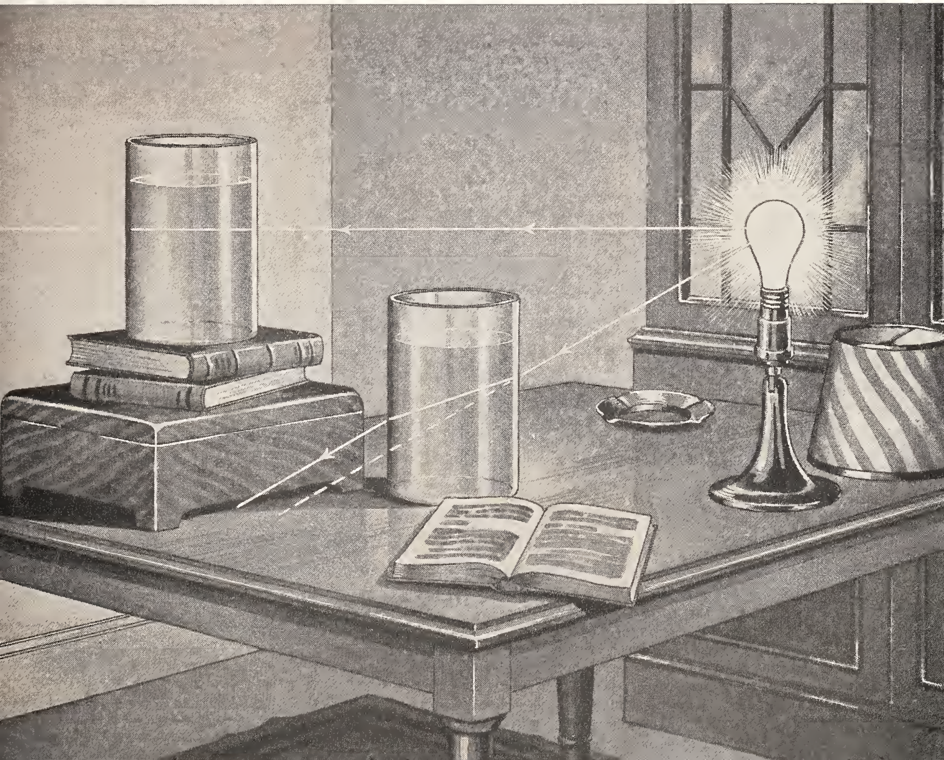
rods. As the object is moved toward the center of the field of vision, its image moves toward the center of the retina. Now it falls on some cones and one becomes aware of color as well as greater detail, since the nerve fibers are more numerous in this part of the eye. Finally, the image falls on the tiny area packed with cones, and the object with all its colors is seen in detail.

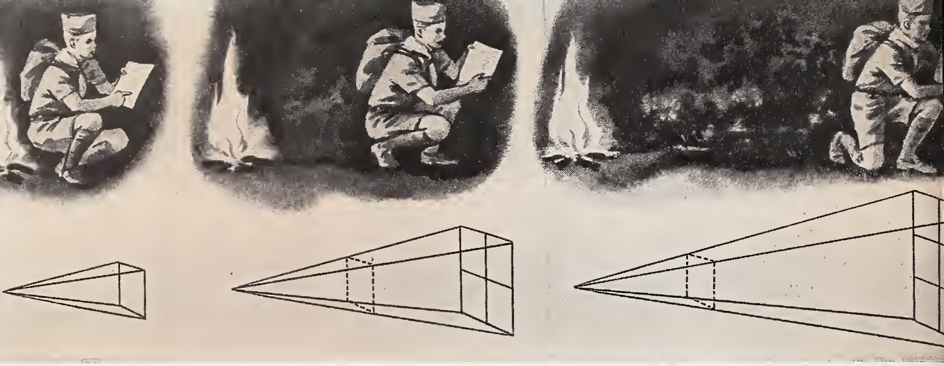
Persistence of vision. When an image is removed suddenly from the retina, its effect does not stop instantly. In other words, some effect seems to remain, or *persist,* after the image is gone. If wave lengths of light that cause red, blue, and green are presented to the eye in order and at a sufficiently rapid rate, such as 30 times per second, the cones are still sending "see red" impulses to the brain when blue arrives. They then send both "see red" and "see blue." Before these stop, green comes along, so they send all three at the same time, and as a result one sees white. This action of the eye in blending individual images together is known as *persistence of vision.* The retina also shows persistence of vision for black and white images. The movement seen in both motion pictures and on television screens is due to this behavior of the eye. In both cases, individual still pictures, each a little different from the one ahead of it, are presented at a rapid rate. The eye blends the individual images together, and we see smooth movement rather than a series of still pictures.

Seeing color. The sodium-vapor lamps used to light streets and highways appear yellowish in color. When light from a neon sign strikes the eye, color is seen. In both of these cases, the range of wave lengths of the light seen was severely limited as compared to sunlight. These examples plus many others indicate that when light having a limited range of frequencies strikes the cones of the eye, the nerve sensations sent to the brain are such that a color is seen. The exact color depends primarily upon the wave length of the light. Thus light with a wave length of about 700 $M\mu$ is seen as red, that of about 500 $M\mu$ as green, while a wave length of about 450 $M\mu$ is seen as blue (see color drawing facing page 216).

Sunlight contains light of all frequencies in about equal amounts (see page 179). Therefore, its source, the sun, would appear white if it could be seen directly. (Do not look directly at the sun). From this fact one might assume that it would be necessary for all wave lengths to strike the cones to make a light source appear white. However, experiments show that such

The arrows indicate the paths of light rays from the lamp through the center of each glass of water. Those passing through one glass are refracted while those passing through the other are not. Only the slanting rays that enter or leave a substance are refracted in the way shown.





Illumination decreases rapidly as distance from the source of light increases. At 3 feet from the camp fire, the light rays illuminate one square, at 6 feet four squares, and at 9 feet nine squares. In other words, although the boy on the right is only three times farther from the fire than the boy on the left, he has only one ninth as much light on his map.

is not the case. In fact, the proper combination of frequencies that produce blue, green, and red is all that is needed on the cones for the mind to see white. Furthermore, by combining these three, or any two of them, in different amounts, it is possible to make one see a great variety of colors other than blue, green, and red. Because of this fact these colors are called the *additive primary* colors (see color drawing facing page 216).

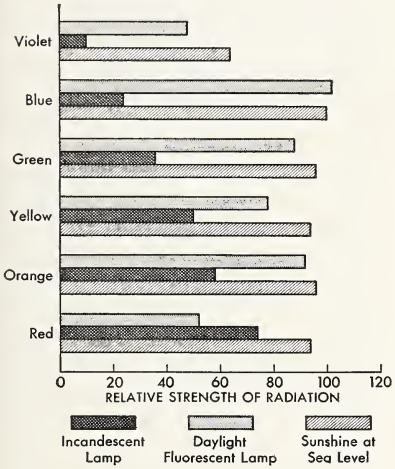
Colored objects. Light sources which produce light of a limited frequency range are seen as colored. Neon lamps, sodium-vapor street lamps, pastel fluorescent lamps, and ore seen under "black light" (see picture facing page 185) are examples of this type.

Light sources often are made to appear colored even though they are not. This is accomplished by allowing the light to pass through some material that stops all except a very narrow band of wave lengths. The familiar green traffic light is a white source covered by glass which stops all except the wave length that causes one to see the color green. Therefore, the glass is called a filter (see page 35). Red and amber filters are used for the other traffic lights. A white source with an appropriate filter is the most common way of obtaining light containing only certain wave lengths.

If an object appears red when illuminated by the sun, it will appear red only where red-producing wave lengths fall on it. It will appear brown or black when illuminated by light lacking the red-producing wave lengths. This shows that the color of an object seen by reflected light (red, brown, and black in this case) depends upon the wave lengths it selects from the light striking it to reflect to the eye. Note that the color depends upon two factors: first, the wave lengths present in the illuminating light, and second, the wave lengths reflected to the eye. A navy blue suit or dress appears to be blue in daylight because it reflects to the eyes those wave lengths which cause one to see the color blue. The same suit or dress appears to be black when seen in artificial light which is weak in the blue-producing wave lengths (see page 179). This is the reason for matching colored cloth in the daylight rather than artificial light.

Good vision. Vision is one of the most valuable abilities we possess. Good vision depends not only upon the kind and the amount of illumination, but also upon the proper functioning of the eye. If the illumination is incorrect or if the eye is not functioning properly, vision is impaired.

Illumination for good vision. Not all light contains the same amount of the various color-producing frequencies. The light from three different sources has been analyzed, and the results are shown below. Thus it is quite clear that an object might not appear to be the same color in light from each of these sources. Vision would be most accurate, and thus best, in light with frequency-content most nearly equal to that of sunlight.



Illumination must be sufficient for good vision. The unit most commonly used for measuring illumination is the *foot-candle*. A foot-candle meter is placed on the surface whose illumination is being measured. The intensity of illumination in foot-candles is then indicated on the dial. When the sun is brightest, it illuminates a surface with about 9,600 foot-candles.

If a foot-candle meter were placed one foot from a light source and the meter registered 60 foot-candles, you might expect it to register one-half as much when placed two feet from the light source. However, it will register only about one-fourth as much, or 15 foot-candles. At three feet it would register one-ninth as much as at one foot, or about 6.6 foot-candles. The illumination of a surface decreases rapidly as the distance from the light source increases. If you study the drawing on page 178, you will understand why this is so. In choosing a place to read, always bear in mind that illumination decreases rapidly the farther you go from the source. Therefore, do not sit too far from the light.

For good vision, the contrast between the illumination of your work and that of your surroundings should not be too great. If your work is brightly lighted and the rest of the room is dark, each time you look away from your work the muscles in your eyes must open or close the pupil in order to adjust to the different amounts of light. Your eyes become tired sooner than they would if illumination were more uniform.

If a light is improperly placed when you are reading, there may be a bright spot on the paper. The bright spot is called *glare*. It is very difficult to see clearly inside the area covered by glare. Glare can be avoided by illuminating your work from the side or from behind.

The best illumination for good vision is secured from a source which spreads the light evenly. Such light is called *diffused* light. A sufficient number of windows properly placed in a room will provide diffused light from the outside during the day. Glass bricks can be used to admit additional light. Artificial lights should be arranged so that the light is spread throughout the room. Light colors on walls and ceilings diffuse light throughout the room. The light-reflecting values of the most commonly used colors are shown in the table at top of the next column.

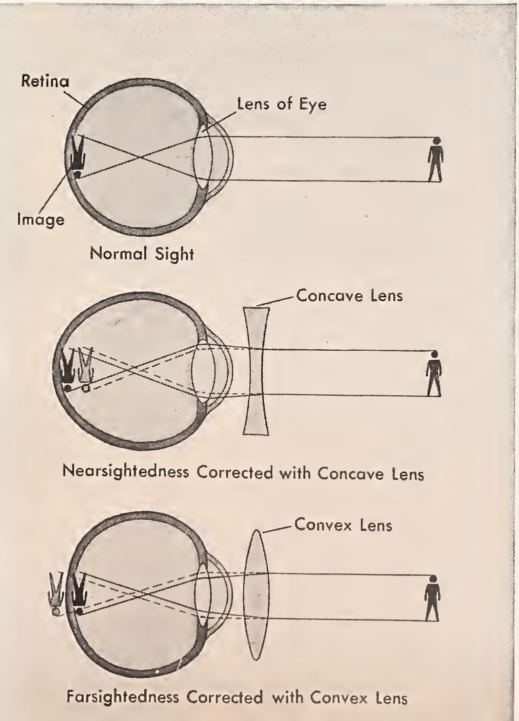
You will find some suggestions for good illumination with incandescent lamps on page 181.

Color and safety. Proper use of color helps prevent accidents. Industrial plants can be made safer by wise use of color, even though a foot-candle meter shows that there is adequate illumination. In such plants, red is used to warn of danger and fire hazards. Orange or yellow, easily visible, is used to attract attention to the overhead moving equipment, so that workmen will not fail to see it as they move about. The traffic lanes are gray, bordered with orange or red, to set them apart from the rest of the floor. The walls are painted in soft colors which do not distract attention from the work, yet help diffuse light throughout the room. During World War II the United States Army was able to reduce disabling injuries from an average of 13.25 per 1,000,000 man-hours worked to 6.99 by the proper use of color in one of its large quartermaster depots. See facing pages 472-473 for pictures illustrating effective use of color as a safety factor.

LIGHT-REFLECTION VALUES

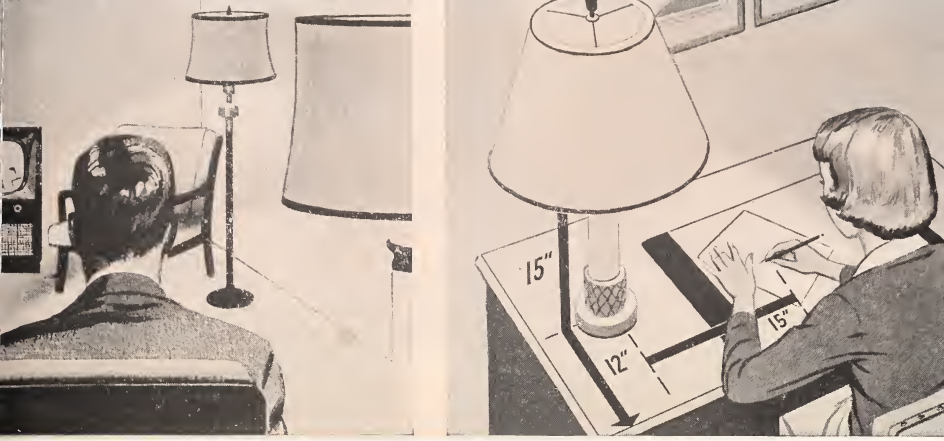
	PER CENT
Light—almost white	85
Cream	70–75
Yellow	55–65
Green	35–50
Blue	10–50

The eyeball shape may cause near- or farsightedness. Instead of allowing light to travel along the dotted lines to produce images out of focus, lenses refract the light to bring the image in focus on the retina.


Retina
Lens of Eye
Image
Normal Sight
Concave Lens
Nearsightedness Corrected with Concave Lens
Convex Lens
Farsightedness Corrected with Convex Lens

Color can also be used to make homes safer. Floors in dimly lighted parts of the home should be painted a light color. The bottom step of a stairway or a poorly lighted doorway stands out if painted white. Basement electric switches, furnace-door handles, and fire extinguishers stand out if they are painted a bright red. This makes it possible to recognize them quickly.

The eye and good vision. Even though illumination is adequate, many people do not have good vision because of defects in the structure of their eyes.



General Electric

Always have light on when viewing television at night, as shown at left. Use floor or table lamps and position them so they do not form reflection on screen. Near desk, the wall should be light colored but not shiny. Avoid using dark colored shades or shades that are bright when lighted. About 40 foot candles on work is desirable. A pastel blotter on desk will help reduce contrast.

The most common defects are *nearsightedness, farsightedness,* and *astigmatism*. On page 180 you can see how the shape of the eyeballs may cause two defects, and how lenses are used to correct them.

When the cornea of the eye is uneven, vision is blurred and the person is said to have astigmatism. This too can be corrected by special lenses.

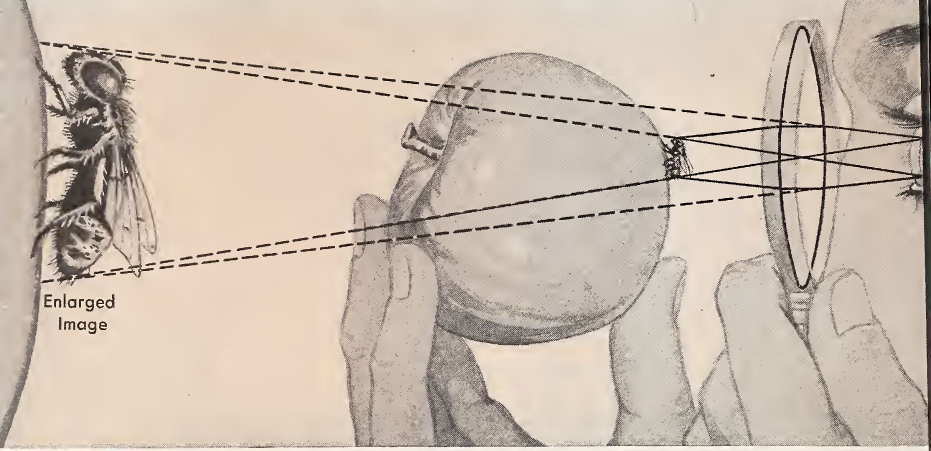
Care of eyes. Good vision is so important in successful living that you should take proper care of your eyes. Here are some helpful suggestions:

1. If you get headaches when reading or studying, or if you do not see the writing on the blackboard clearly, have your eyes examined.
2. Be sure to provide illumination for good vision. This means a sufficient amount of good light, with a minimum of glare and contrasts. Be sure to have some lamps in the room turned on when watching television at night.
3. When you are doing close work, look away from your work occasionally to give your eyes a chance to rest.
4. Use extreme care in removing a foreign object from the eye.
5. Take special precautions when you are engaged in activities where the eyes may be easily damaged.

INSTRUMENTS TO AID VISION

When man first realized that there might be many objects in his environment that were either too small or too far away to be seen with the unaided eye, he became curious about them. As a result of this curiosity, he developed instruments to aid him in seeing the "unseen." Instruments that produce enlarged images of tiny objects are called *magnifiers* if they are simply constructed, and *microscopes* if they are more complicated.

A microscope is a double magnifier. The lower, or *objective,* lens produces an image inside the microscope, but



A simple magnifier consists of a convex lens mounted in a suitable frame. When it is placed near a small object, such as this fly, light rays travel to the eye, as shown by the solid lines, but the eye sees an enlarged image of the fly, as indicated by the dotted lines.

there is no screen. Instead, this image serves as an object for a lens in the *eyepiece,* which magnifies the image again as a simple magnifier would enlarge it. The image seen in the microscope may be as much as 5,000 times as wide as the original object.

Magnifiers and ordinary microscopes project images by means of visible light, but some objects are far too small to be observed in this way. Such objects can be studied with the *electron microscope,* in which electrons are used instead of visible light rays. With this microscope, scientists have been able to photograph the shadows of very tiny objects.

We have learned that two types of telescopes, the refracting telescope and the reflecting telescope, are used for observing heavenly bodies. The principles on which these work are shown on page 99.

Taking pictures. Although there are many different types of cameras, all cameras operate on the same principle as the pinhole camera. An inverted image is formed by the lens on a film coated with chemicals that are affected by light. The extent of the chemical change depends upon the strength of light. The white parts of an object reflect more light toward the camera and cause a greater change in the chemicals on the film than the darker parts of the object. In this manner, the various parts of an object are recorded in shades of black and white. The film is then developed to form a negative. The negative is used to reproduce pictures of the object.

Television broadcasting. Television broadcasts make it possible actually to see as well as hear the events being broadcast. The first step in broadcasting a scene is to change light into electric impulses. This is accomplished by the television camera, which contains an electron tube designed especially for this purpose. Three such tubes used in television cameras are the *iconoscope,* the *orthiconoscope,* and the *image orthicon.*

The iconoscope. The iconoscope is

one of the first successful electron tubes used in a television camera. A drawing of an iconoscope is shown on page 185. The iconoscope changes light to electric impulses in the following manner. A glass lens in the camera focuses an image of the scene to be broadcast upon the surface of a light-sensitive plate, called a *mosaic,* inside the tube. The mosaic is made of an insulator upon which have been deposited a great many tiny silver beads, each coated with the metal *caesium.* The beads are insulated from each other. The back of the mosaic is covered with a good electric conductor. When light strikes the beads on the mosaic, the caesium gives off electrons. The number of electrons given off by each bead depends upon the amount of light striking it. Those which are brightly lighted give off more electrons than those which are not. As each bead loses electrons, it becomes positively charged. Thus the scene focused on the mosaic has been changed into a pattern of electric charges. The amount of charge on each part of the mosaic is determined by the intensity of light reflected to it from the scene.

The next step is to change the pattern of electric charges on the mosaic into electric impulses. This is accomplished with a thin beam of electrons shot out of the *electron gun* in the neck of the tube. The electron beam is so controlled that it *scans,* or moves back and forth, across the mosaic. The beam makes 525 trips across the mosaic to scan the image once. The image is scanned by the beam 30 times each second. The beam, as it strikes each of the beads on the mosaic, gives up electrons to replace those driven off the bead by the light forming the image. This causes a small electric impulse to travel from the conductor on the back of the mosaic into the television transmitter. The strength of the impulses depends upon the amount of positive charge the beads obtained when the beam of light struck them. Thus a series of impulses, each depending upon the amount of light in different parts of the image, is sent to the transmitter. These impulses, each representing a tiny part of the image, are used to modulate the radio wave that is transmitted from the television station.

The orthiconoscope and image orthicon. The orthiconoscope, often called *orthicon,* is an improvement over the iconoscope. In it the mosaic is *translucent,* that is, it will allow the light to pass through it, although you cannot see objects through it. The scene is focused on one side of the mosaic and the electron beam scans the other side. In the orthicon, the electrons leaving the electron gun are focused into a narrower beam than in the iconoscope. These and other improvements have made the orthicon about ten times more sensitive to light than the iconoscope. This increased sensitivity makes it possible to televise scenes that are much less brilliantly lighted. With the orthicon, it is possible to broadcast satisfactory pictures of outdoor scenes even on cloudy days. Further improvements have led to the image orthicon, 100 to 1,000 times more sensitive than the orthicon.

The electric impulses from the television camera are amplified by electron tubes similar to those in a radio and are then used to modulate a carrier wave. The carrier wave of each television station requires a band of frequencies six megacycles wide. The band of frequencies occupied by a station is called a *channel.* There are 82 channels used by television stations.

Television reception. As the carrier wave, modulated with electric impulses produced by the camera, moves past the television receiving antenna, it develops electric impulses in the antenna. These impulses are amplified by electron tubes and cause the image to be reproduced in the receiver.

In most black and white television receivers, the picture is reproduced upon the face of a large electron tube called a *cathode-ray* tube (commonly called the picture tube). An electron gun similar to that in the camera tube is located in the neck of the cathode-ray tube. A beam of electrons shot out of the gun strikes the inside surface of the tube. A coating of chemicals, called *phosphors,* that will produce light when struck by electrons covers the inside face of the tube. The signals coming from the television station are applied to the tube in such a way that the electron beam scans the face of the cathode-ray tube in exact step with the beam that scans the scene in the studio. The strength of the beam is also changed in accordance with the amount of light reflected from the various parts of the scene being broadcast. Thus the light and dark parts of the scene are reproduced as light and dark parts of the picture on the cathode-ray tube. In this manner the electron beam in the cathode-ray tube reproduces the scene in the television studio.

Broadcasting color television. In order to broadcast color television, it is necessary to modulate the carrier wave with three series of impulses from each scene. These impulses represent the red (615 $M\mu$), the green (538 $M\mu$), and the blue (460 $M\mu$) in the scene. They are obtained by using three ordinary camera tubes, each equipped with the appropriate light filter.

The impulses from these three cameras are mixed in the percentage necessary to produce white from these three colors: red 30 per cent, green 59 per cent, and blue 11 per cent. The result is called the *Y signal.* The Y signal takes the place of the signal that would be obtained from an ordinary black and white camera. When an ordinary black and white television receiver is tuned to a color carrier which is modulated with the Y signal, it responds only to the Y signal and reproduces the picture in black and white. Thus black and white receivers will still operate even though the stations are broadcasting for color receivers. The impulses from the color cameras are mixed in other proportions to form two additional signals known as the *Q* and *I signals.* These are the special color signals which are also impressed upon the carrier wave. A color receiver responds to these, as well as to the Y signal, to produce a color picture.

Receiving color television. The heart of a color television receiver is the color picture tube. Like those used in black and white receivers, it is a cathode-ray tube. The viewing surface is covered with tiny dots of three different phosphors, one that glows red, another green, and the third blue when struck by a beam of electrons. In one such 15-inch tube, there are 750,000 dots arranged in groups of three.

In the neck of the tube there are three electron guns, one for each color. Between the guns and the viewing sur-

Philip Gendreau, N. Y.

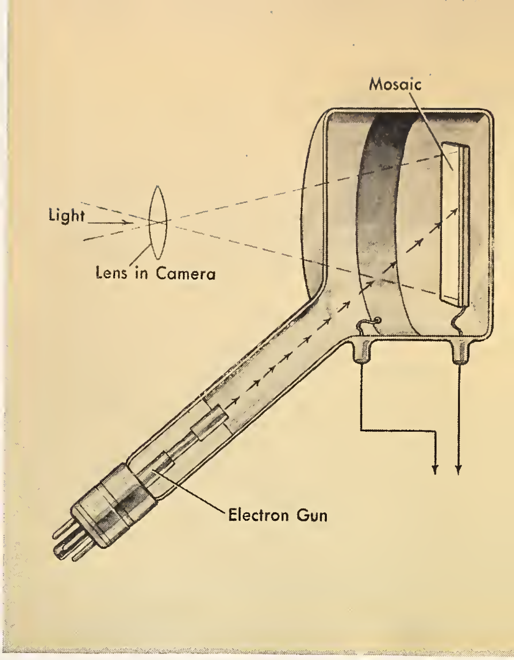
The International Ice Patrol, using radar and loran, collects weather information and data about depth and drift of icebergs, one of the dangers menacing ships in certain oceans.

Ultra-Violet Products Inc.

Ores invisible to the eye under ordinary light burst into brilliant colors under "black light." The ores become a light source just as the phosphor in a fluorescent lamp does. This characteristic of one type of radiant energy makes it a valuable tool for prospectors.

face, but very close to the latter, a thin sheet of metal containing a tiny hole for each group of three dots (250,000 holes in this case) is carefully positioned. The electron beams from the three guns are made to cross each other at the holes in the plate. Since they come from slightly different angles, they spread apart just enough after passing through the plate for the beam from each color gun to strike the corresponding color dot (see diagram, facing page 216).

The Q and I signals contained in a wave coming from the transmitter are separated by the television receiver into three separate signals corresponding to those produced by the red, green, and blue cameras in the studio. These separate signals, plus the Y signal, are fed to the three guns in the receiving tube. The beams from the guns scan the tube face as in a black and white receiver. As they scan the tube, each dot glows red, green, or blue, corresponding to those colors present in the studio scene. Thirty complete pictures are formed each second. Because of persistence of vision, the eyes fuse the separate images into a reproduction for both the motion and the color in the studio scene.



An iconoscope tube used in television cameras. An electron beam from the electron gun scans the image produced on the light-sensitive mosaic, sending electric impulses from the tube to the amplifier, indicated by arrows pointing down.

SUMMARY

Light, as radiant energy, is produced by the movement of electrons in excited atoms. Atoms may be excited by adding energy to the atom with heat, electric discharges, or radiant energy. An object can be seen only if light from some source strikes it and is reflected to the eye, or if the object is the source of light.

Light rays travel in straight lines. They are reflected by certain materials which they strike and are bent or refracted by other materials through which they may pass. Mirrors and lenses are used in reflecting and refracting light in order to control it for improving and extending vision.

The human eye is constructed so that light can be controlled to produce images to make vision possible. When the eye cannot produce clear images, the difficulty can often be corrected by the use of special lenses. Vision can also be aided by the selection of the proper colors for decorating the interiors of buildings and by controlling the intensity of light indoors so that objects stand out distinctly.

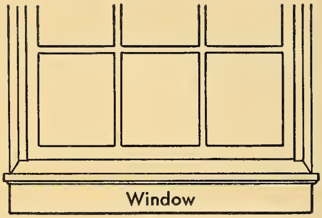
Lenses are used in cameras to form images on photographic film. These images cause chemical changes in the film which result in a permanent record of the image. The result is called a photograph.

In television broadcasting, visible light is converted into electric impulses which are used to modulate radio waves. Television receiving sets use the modulated radio wave to change electric impulses into visible light, thus reproducing the images which are broadcast.

OBSERVATION

Sheet of White Paper

Convex Lens

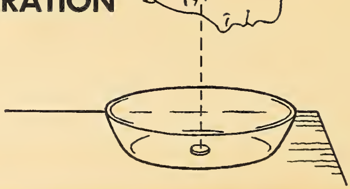


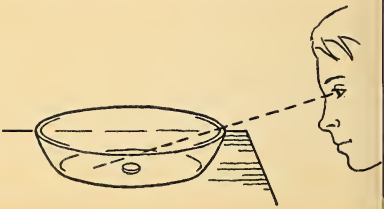
What to observe. The image formed by a convex lens.

How to observe it. Hold a convex lens, such as a reading glass, between some lighted object and a sheet of white paper. (The window of your classroom serves very well as a lighted object.) Move the lens nearer to or farther from the paper until you find a position in which the image of the lighted object appears sharp and clear on the paper. How does the shape and the position of the image compare with the object?

Interpretation of your observation. Write one sentence describing the relationship of the image to the object.

DEMONSTRATION





Generalization to be demonstrated. As light rays pass from one material to another they may change the direction in which they are traveling.

What you need. A flat-bottomed dish; a small coin; some water.

What to do. 1. Place coin on the bottom of the dish and stand so that you can look directly down upon the coin. Now have someone pour water into the dish, being careful not to move the coin.

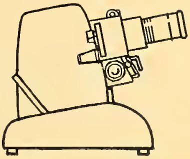
2. Place the coin on the bottom of the empty dish and stand so that the rim of the dish just hides the coin from view. Again have someone pour water into the dish, being careful not to move the coin.

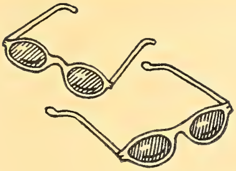
What to observe. What does the coin appear to do as the water is poured into the dish?

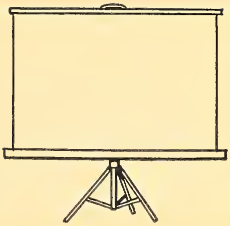
Some basic assumptions. 1. Light travels in straight lines. 2. Light traveling from the coin to your eyes makes it possible to see the coin.

What does it mean? How does the apparent movement of the coin give evidence to support the generalization? Could the word "may" be omitted from the generalization? Give your reasons.

XPERIMENT







Problem to be solved. Do sun glasses affect clarity of vision?

What you need. A number of ordinary sun glasses (do not use prescription glasses in which the glass is ground to correct eye defects); a lantern for projecting slides; a slide that will form a sharp image on a screen; and a projection screen.

What to do. Focus the slide sharply upon the screen. Place the sun glasses being tested in front of and as near to the lens of the projector as possible so that light must pass through the sun glasses when the slide is projected on the screen. Compare the sharpness of the image on the screen with and without the sun glasses.

Some basic assumptions. 1. Clarity of vision depends upon a sharp, clearly defined image on the retina.

2. The color of the glass does not affect clarity of vision.

Your answer. 1. How did the different sun glasses you tested affect the sharpness of the image?

2. What precautions should you observe in selecting sun glasses?

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The action which takes place when light from some source strikes an object and then travels from the object to the eyes is known as (a) refraction; (b) reflection; (c) illumination; (d) magnification.
2. If an object is flooded with light, it is said to be (a) luminous; (b) incandescent; (c) illuminated; (d) transparent.
3. The cathode-ray (picture) tube in a television receiver changes (a) light into electric impulses; (b) electric impulses into light; (c) electric impulses into sound; (d) electric impulses into vision.
4. If the image falls ahead of the retina of the eye, a person (a) is nearsighted; (b) is farsighted; (c) has astigmatism; (d) has good vision.
5. In a television camera, electric impulses are produced from (a) sound; (b) heat; (c) light; (d) vision.

PROBLEM 4. How do we use ultraviolet rays?

NATURE OF ULTRAVIOLET RAYS

Another type of radiant energy, *ultraviolet rays,* has higher frequencies and even shorter wave lengths than visible light. The human eye is not sensitive to them, but they are known to be present in sunlight because of the effects they produce. Let us see how man has learned to produce and control ultraviolet rays.

Sources of ultraviolet rays. The greatest natural source of ultraviolet rays is the sun. However, when sunlight reaches the surface of the earth, it does not possess all the ultraviolet rays which were present before it entered the earth's atmosphere. It is fortunate for us that the shorter ultraviolet rays are absorbed by the atmosphere, for many of them would burn our bodies very severely if we were exposed to them.

Ultraviolet rays can be produced artificially by specially designed electric lamps. One such lamp, called the *sun lamp,* consists of a tungsten filament supported in a bulb made of a special type of glass and containing a small pool of mercury. When an electric current is passed through the filament, the filament becomes hot and heats the mercury changing some of it to a vapor. A stream of electrons passing through this vapor causes it to give off ultraviolet rays. Ultraviolet rays produced by the mercury sun lamp have about the same frequencies as those in sunlight.

Effects of ultraviolet rays. Ultraviolet rays of certain frequencies are often called "black light." Though they are invisible, they cause many substances to glow, or fluoresce, with characteristic colors. When illuminated with ultraviolet rays, ores containing uranium, tungsten, zinc, and mercury, for example, give off visible light of different color (see picture facing page 185). "Black light" is therefore useful to ore prospectors. During World War II, when there was a great need for many of these ores, new sources had to be found. To locate them, trucks and cars equipped with "black light" searchlights were driven through the mountains at night. When directed toward the rock walls of the mountains, these searchlights quickly revealed deposits of ore which were identified by their colors. "Black light" is also used for reading maps and instrument panels in airplanes and for signaling when there is almost total darkness. It makes invisible laundry marks on clothing legible and causes carpets in motion-picture theaters and costumes on a darkened stage to glow.

"Black light" is also an aid in crime detection. It often reveals stains on clothing which cannot be seen in ordinary light and makes visible secret messages written with some kinds of invisible ink.

Ultraviolet rays of certain frequency produce sun tan. High frequency rays, however, if allowed to strike the skin for any length of time, cause painful sunburn. A sun tan with a minimum of sunburn may be acquired in two ways. One way is to begin by exposing the skin to sunlight or sun lamp for very short periods of time and gradually to increase the time of exposure until the skin is satisfactorily tanned. The other way is to use a sun-tan cream or lotion, which will absorb the higher-frequency ultraviolet rays that would burn the skin and will allow only the lower-frequency rays that tan to reach it. Not all sun-tan preparations effectively prevent sunburn.

Vitamin D, sometimes called the "sunshine vitamin," is produced in the body only when a person is exposed to ultraviolet rays, but sun baths are not necessary for its production. Tests with both children and adults have shown that in summer sufficient vitamin D is produced if a person dressed in street clothes spends some time each day in the open.

Ultraviolet rays are also used to increase the vitamin D content in certain foods by a process known as *irradiation*. Irradiation consists mainly of exposing foods to ultraviolet rays for short periods of time. Large amounts of food, especially canned milk, receive this treatment to increase their vitamin D content.

Certain of the higher-frequency ultraviolet rays generated by a special *germicidal lamp* are powerful germ killers. Germicidal lamps are used for sterilizing water, the air in hospital operating rooms, schoolrooms, public buildings, homes, refrigerators, surgical-instrument cases, and so on. They must be installed with care so that their rays will not harm the eyes. The rays also discolor many materials. Some types of white plastic, for instance, turn gray or brown under them. Growing plants may be severely damaged if exposed to them.

SUMMARY

Ultraviolet rays are a type of radiant energy which can be obtained naturally from sunlight or produced artificially by exciting mercury atoms with streams of electrons. They are used to produce vitamin D in the body and in certain foods. Certain of the ultraviolet rays are effective in destroying disease-producing germs, although these rays must be carefully controlled, since they also have a harmful effect upon the body. When ultraviolet rays strike the atoms of certain substances, the atoms be-

come excited and give off a colored light characteristic of the kind of atom that is excited. It is thus possible to use ultraviolet light in discovering precious ores.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the best ending to each of the following statements.

1. The source of ultraviolet rays in a sun lamp is the (a) filament; (b) electric discharge; (c) atoms of mercury vapor; (d) tungsten.
2. Miners use ultraviolet light (a) for sun tan; (b) for prospecting; (c) for vision at night; (d) for reaching a greater depth.
3. The health benefit derived from summer sunshine is (a) vitamin D; (b) sun tan; (c) sunburn; (d) "black light."
4. The vitamin D content of foods is often increased (a) by boiling; (b) by storing; (c) by irradiating; (d) by broiling.
5. We know ultraviolet rays are present in the sunshine because (a) they can be seen; (b) they can be felt; (c) of the effects they produce; (d) they kill germs.

PROBLEM 5. How do we use X-rays?

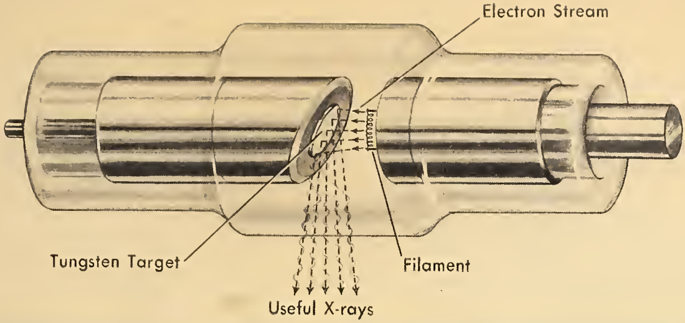
NATURE OF X-RAYS

You are probably familiar with the use of *X-rays* to make pictures of broken bones. Perhaps you do not know that X-rays have many other uses, especially in industry. They have, for example, made automobiles safer by revealing imperfect parts that had to be removed and replaced. It is important that you understand how your life has been affected by the use of this valuable form of radiant energy.

Production of X-rays. X-rays were discovered in 1895 by Wilhelm Roentgen, a German scientist. Although Roentgen discovered some of their most important properties, he did not know what the rays were. He therefore called them X-rays, X standing for their unknown nature. Today scientists believe that X-rays are radiant energy of extremely high frequency and therefore extremely short wave length.

X-rays are produced when rapidly moving electrons strike a piece of metal inside a tube from which the air has been removed. A careful study of the drawing of a small X-ray tube on page 191 will show the principle on which it operates.

Characteristics of X-rays. X-rays can be used for taking pictures because of two important characteristics. One characteristic is that they do not pass through all substances to the same extent. A bone, for example, stops more rays than flesh does. A metal ring or bracelet stops even more than bone does. The second important characteristic of X-rays is that they affect a photographic plate just as light affects it. When a photographic plate which has been exposed to X-rays is developed, the part where the greatest amount passed through appears darker than where only a small amount passed through. Thus, a shadow picture of



When the filament is heated by having electricity passed through it, electrons in large numbers are forced out of it. Since the tungsten target has a high positive charge, electrons are pulled toward it at high speed. When these electrons strike the target, its atoms emit useful X-rays.

the interior of the exposed object is obtained.

X-rays at work. X-ray pictures are taken for many purposes. They are an accurate means of locating imperfect parts in automobile and airplane engines. Flaws or cracks inside the metal appear on the photographic plate. At Hoover Dam, more than 75 miles of welded joints were X-rayed to be sure that the welds were good. Wood is often X-rayed for wormholes, rot, or nails. An X-ray photograph of the wooden roof of a famous building in England showed that the roof was honeycombed with tunnels of a destructive beetle. Often famous paintings are X-rayed to determine whether they are the originals or whether they have been tampered with. Many forged paintings have been discovered with X-rays.

The most important use for X-rays is in diagnosis and treatment of disease. X-ray pictures of the lungs, for instance, show whether a person has tuberculosis. Some diseases of the stomach and other internal organs can be diagnosed by the use of X-ray pictures. X-rays are also helpful in treating certain diseases such as cancer.

Often there is no need for a permanent record of an X-ray examination. In such cases, an object is placed so that the X-rays passing through it strike a screen coated with certain chemicals which glow when the X-rays strike them. A shadow picture of the object appears on the screen, which is called a *fluoroscope*. Fluoroscopic examination is especially valuable when large numbers of similar objects must be inspected for a specific purpose. Golf balls, for example, are fluoroscoped to see if the core is properly centered. By use of the fluoroscope, juicy citrus fruits can be separated from the crystallized fruits. Boxed and bulk foods are examined for foreign matter, such as wire, bits of metal, and stones. Cigarettes can be counted inside a package.

X-rays have also been used in developing new types of plants and animals; methods for doing this, as well as for treating diseases, will be described in greater detail in a later unit. X-rays are dangerous and should not be used by inexperienced persons, because if they are used for too long a time, they destroy tissues of the body.

SUMMARY

X-rays are a form of radiant energy produced by atoms of certain substances when bombarded by electrons. It is possible to produce and control X-rays in order to take pictures of the interiors of solid objects. When permanent pictures are not desired, the interior of objects can be examined with a fluoroscope.

TEST YOURSELF

Write the letter of the best ending to each of the following statements in the proper place on your answer sheet.

1. The nationality of the scientist who is given credit for first dicovering X-rays was (a) American; (b) German; (c) Russian; (d) Dutch.
2. Compared with ultraviolet rays, the frequency of X-rays is (a) lower; (b) higher; (c) the same; (d) shorter.
3. The substance which will absorb X-rays the most is (a) flesh; (b) bone; (c) metal; (d) cloth.
4. When a permanent record is not wanted, the instrument used for examination with X-rays is (a) the fluoroscope; (b) the microscope; (c) the camera; (d) the germicidal lamp.
5. X-rays are dangerous if not properly used because (a) they kill cells; (b) they affect photographic plates; (c) they are easily produced; (d) they have a high frequency.

CHAPTER ACTIVITIES

REVIEW YOUR UNDERSTANDING

1. Below are listed several facts about the way different types of radiant energy, about which you have read in this book, are produced. Following the set of facts are three generalizations. On your answer sheet, write the letter of the generalization which is best supported by all preceding facts listed.

FACTS

1. Rapidly moving electrons may produce X-rays when they strike the atoms of a metal target.

2. Electrons striking atoms of mercury inside a fluorescent lamp produce ultraviolet rays.

3. When the atoms of a metal stove are heated, infrared rays are given off.

4. When the metal filament of an incandescent lamp is heated white hot, it produces light.

5. When ultraviolet rays fall upon the atoms of certain chemicals, visible light is given off.

GENERALIZATION

a. Atoms can be excited in various ways so that they will produce different types of radiant energy.
b. Radiant energy affects substances in different ways.
c. Many uses have been found for the different types of radiant energy man has been able to produce.

TEST A HYPOTHESIS

In the experiment on page 187, it was assumed that the color of the sun glass does not affect clarity of vision. As long as you are willing to accept this statement as true, it is an assumption. But if you should want to be sure it was true, you might treat it as a hypothesis, and test it. On your answer sheet, write the numbers of the statements which describe the best procedures for testing this hypothesis.

1. Test, by the method used in the experiment on page 187, both expensive and inexpensive sun glasses of the same color.
2. Test, by the method used in the same experiment, inexpensive sun glasses of many different colors.
3. Test, by the method used in the same experiment, expensive sun glasses of many different colors.
4. Test, by the method used in the same experiment, both expensive and inexpensive sun glasses of different colors.

RECOGNIZE ASSUMPTIONS

If you should conclude from the evidence obtained in the experiment on page 187, that sun glasses vary in their effect upon clarity of vision, there is at least one other assumption you will have to accept in addition to those listed in the experiment. On your answer sheet, write the number of the sentence below which best states that assumption.

1. Expensive sun glasses are always better than inexpensive sun glasses.
2. The sun glasses tested will affect the image on the retina of the eye in the same way they affected the image on the screen.
3. All inexpensive sun glasses affect the image on the screen the same way.

UNIT ACTIVITIES

APPLY YOUR KNOWLEDGE

1. Below are listed a number of generalizations about radio waves. Following them are listed a number of statements describing situations in which radio waves are used. After the letters of each situation, write on your answer sheet the number of each generalization which helps explain the situation.

GENERALIZATIONS

1. Radio waves travel at approximately 186,000 miles per second.

2. Radio waves may be reflected from, transmitted through, or absorbed by the objects they strike.

3. Radio waves can travel through empty space.

SITUATIONS

a. Radar has been used to contact the moon.
b. Communication between distant parts of the world is almost instantaneous when radio waves are used.
c. Reception from automobile radios often fades away when the automobile passes under bridges or trestles.
d. Many radios do not have outside antennas.
e. Radar can be used to locate the distance and position of objects.

4. On your answer sheet, write a letter for each of the situations listed below. After each of these letters, write the number of the generalization which helps explain the situation.

GENERALIZATIONS

1. Light may be reflected from, transmitted through, or absorbed by the objects it strikes.
2. Light travels in straight lines.
3. Light may change its direction when it passes from one material to another.

SITUATIONS

a. The ceilings of rooms are usually painted a light color.
b. Storage bottles for some chemicals are made of colored glass.
c. Eclipses of the sun occur when the moon passes between the sun and the earth.
d. Ponds of clear water often appear to be more shallow than they really are.
e. Many eye defects can be corrected by using lenses.

INCREASE YOUR UNDERSTANDING

1. Plan a demonstration to show that radio waves are produced by an electric spark.

2. Prepare an assembly program on radiant energy. Plan to use demonstrations to show ways in which we depend upon radiant energy.

3. Visit a "fun house" and examine the mirrors used to make people look "funny." What kinds are in use?

4. Visit an eye specialist to discover how eyes are tested and how defects are corrected.

5. Make a survey of illumination in your school, and prepare a report making recommendations if improvements are needed.

READ ABOUT RADIANT ENERGY

Adler, Irving. *Secret of light*. New York: International Publishers, Inc., 1952.
Exciting book explaining light, with many interesting facts about its behavior under different circumstances. Simple experiments dealing with electromagnetic waves.

Bendick, Jeanne, and Bendick, Robert. *Television Works Like This*. New York: Whittlesey House, 1953.
The large cartoon-like drawings in this book will help you to learn more about television.

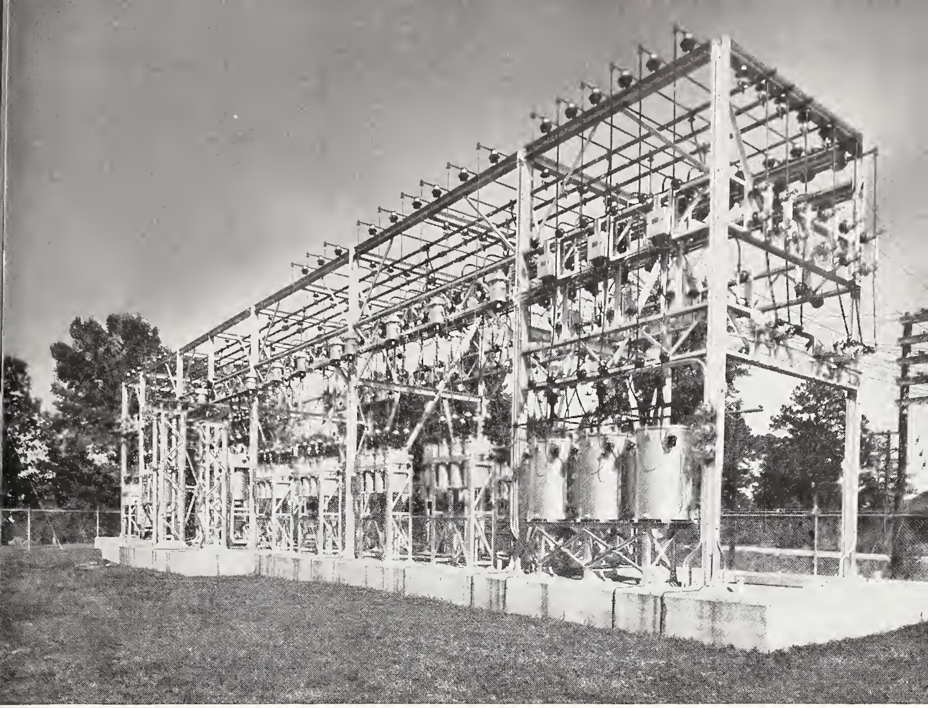
Bowler, Stanley W. *Photography for Boys and Girls*. New York: Thomas Y. Crowell Company, 1952.
Useful book for beginning photographers.

Larsen, Egon. *Radar Works Like This*. New York: Roy Publishers, 1953.
Good explanation of radar.

Minnaert, M. *Nature of light and colour in the open air*. New York: Dover Publications, 1954.
This book tells why the rainbow is multicolored and why falling snow is sometimes black.

Morgan, Alfred. *The Boys' First Book of Radio and Electronics*. New York: Charles Scribner's Sons, 1954.
The author has placed emphasis on equipment the reader can build for himself.

Schwartz, Julius. *Through the Magnifying Glass, Little Things That Make a Big Difference*. New York: Whittlesey House, 1954.
Experiments done with simple lenses and viewing stands, on a variety of curious creatures are described. You will also learn how to detect counterfeit money.



Westinghouse

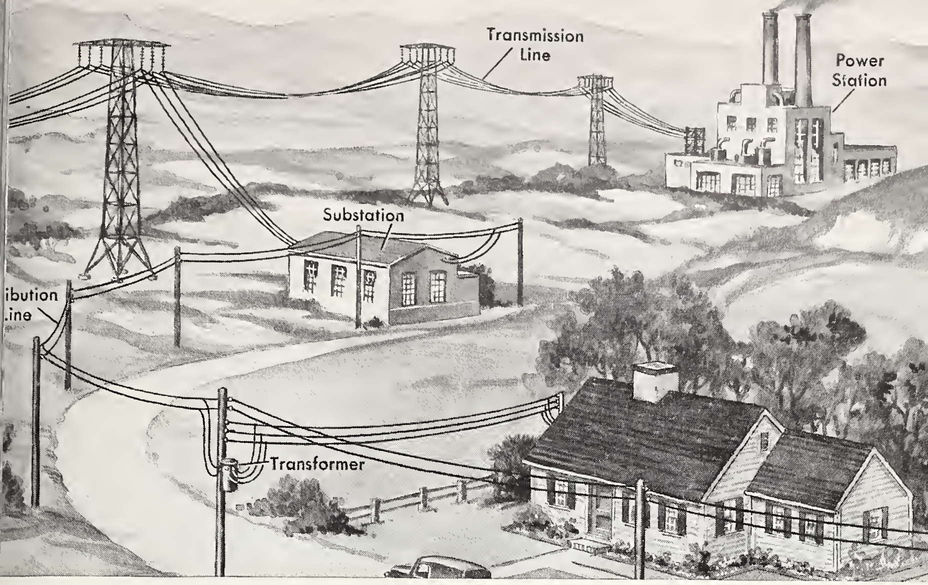
An electric power substation, symbol of our dependence upon electricity. The large cans contain transformers needed to change voltage.

unit 5 ELECTRICITY

HAVE you ever considered how much we depend upon electricity in our everyday living? If we were to lose our knowledge of how to produce and use electricity, our way of living would be greatly changed. We would no longer have electric lights. Electric trains could not be operated, nor would it be possible to run our automobiles. There would be no telephone, telegraph, radio, or television. We could not have modern laundry machines, vacuum cleaners, electric refrigerators, automatic heating systems, or any other devices operated by electricity. In fact, without electricity our present way of living would be impossible.

When we snap the switch to turn on the lights, the television set, or any other electric device in our homes, we seldom think of all the problems which had to be solved before electricity could be brought to our homes and used to work for us. First, the electricity had to be produced in a usable form. Then it had to be transmitted from the place where it was produced to our homes. And finally the many electric devices had to be built so that the electricity could be put to work.

In this unit you will learn how electricity is produced, how it is transmitted from place to place and distributed to our homes, how it is measured, and how it is used in the many electric devices in homes and in industry.



The voltage of electricity generated in power plants is increased by step-up transformers to several hundred thousand volts for transmission to substations. There the voltage is reduced by step-down transformers to several thousand volts. In transformers near the home voltage is further reduced before the current is transmitted to each home where it is used.

chapter 10 ELECTRICITY FOR HOME USE

ELECTRICITY is widely used because it can easily be produced and transmitted great distances. Other forms of energy, such as that from falling water and heat, must be used near the places at which they are produced. Machines operated by falling water, for example, are located reasonably close to the supply of water on which they depend. Those operated by heat energy released from burning fuel are situated very near the place where the fuel is burned. Electricity, however, can be produced in one place and transmitted hundreds of miles away to be used for many purposes. The development of electric power stations and systems for transmitting and distributing electricity has made it possible for most homes to be supplied with electricity.

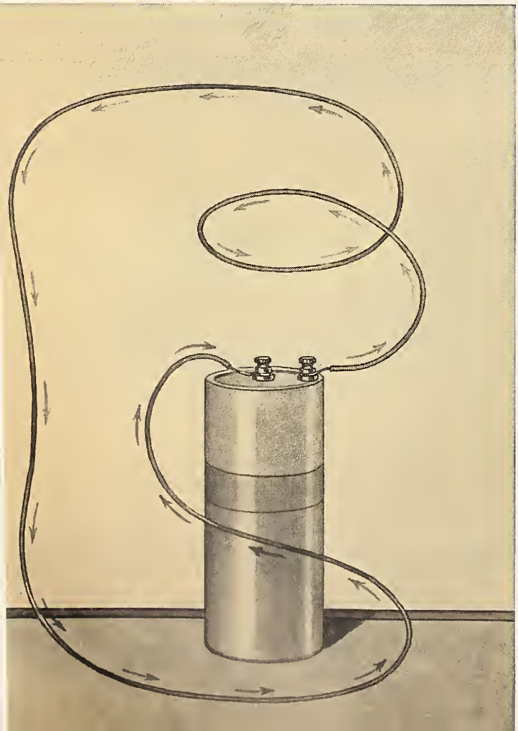
PROBLEM 1. How is electricity produced for our homes?

KINDS OF ELECTRICITY

Static electricity. As we learned in Unit 4, electricity is believed to be the movement of electrons in a conductor. The electrons, which come from atoms, are the "stuff" of which electricity is made.

You will recall that when a rubber rod is rubbed with fur, it becomes negatively charged. The negative charge is produced by electrons being rubbed off the fur onto the rubber rod. Since the rod is a nonconductor, the electrons do not move through it but collect where the rod is rubbed. These electrons are known as *static electricity*. Static electricity is often produced when two surfaces rub against each other. For example, you have probably had the experience of walking across a wool rug and being "shocked" when you touched a door knob. The "shock" was caused by static electricity, produced by your shoes rubbing against the rug.

The arrows indicate electrons traveling from the outside post (negative) to the center post (positive) of a cell. In D.C., the current travels only one way, from negative to positive.



Static electricity is of little practical use. In fact, it is often dangerous, and precautions must be taken to prevent it from accumulating. For example, trucks traveling along a highway sometimes become charged with static electricity. If a gasoline tank truck should become thus charged, a spark might be produced which would cause the gasoline to explode. To prevent such an accident, a chain is suspended from the bottom of the truck to conduct the static electricity to the earth as soon as it is formed. Thus there is never enough static electricity on the truck to produce a spark. Dry cleaning with gasoline, too, may be dangerous. When silk is rubbed with gasoline, sometimes enough static electricity is produced to cause a spark, which may set the gasoline fumes on fire, causing severe burns. For safety, a noninflammable fluid should always be used for dry cleaning.

Current electricity. There are two types of electric current. In one type the electrons always move in the same direction within the substance that is conducting them. As shown at the left, although the wire conductor may be arranged in many positions, the electrons never change the direction of their movement within it. This type of electric current is called *direct current* (usually abbreviated *D.C.*). It is seldom used in homes because it cannot be transmitted so easily as another type, *alternating current.*

In this second type of current, the direction of the motion of the electrons within the conductor is constantly being reversed. The electrons are caused to move back and forth within the conductor. This alternating current (abbreviated *A.C.*) is used in most of our homes.

ALTERNATING CURRENT

The electric power station. The electricity for our homes is produced by machines called *generators,* which are housed in a building known as the *power station.* A force is needed to operate them. Sometimes the force of falling water is used; but when water is not available, the force may be developed by steam or Diesel engines. These engines are housed with the generators in the electric power station.

Producing alternating current. Although a generator looks very complicated, it has only two main parts: the *armature* and a number of magnets. The armature, consisting of numerous coils of copper wire, is surrounded by several magnets which produce a magnetic field. The armature does not touch the magnets. When the armature is rotated, its coils of wire cut across the lines of force in the field of the magnets. In so doing, a force is exerted on the electrons in the coils. This force causes them to move first in one direction and then in the opposite direction. This force is called an *electromotive force.* It is measured in units called *volts.* It can be produced by rotating either the armature or the magnetic field while the other remains stationary. *Volts* and *voltage* are used only in describing electromotive force, and are never used in describing an electric current. If the armature wires are connected to an electric device, such as a lamp, the force on the electrons in the armature wire causes the electrons to move back and forth in the lamp, producing an alternating current of electricity. As the electricity is produced by the generators in the power station, it is transmitted along wires to our homes.

Characteristics of alternating current. Alternating current seems to be very much like radiant energy except that it travels almost entirely in a conductor rather than through space. Like radiant energy, it possesses electric and magnetic fields. These fields change in strength regularly in cycles, just as the radiant energy wave does. The frequency of an alternating current is determined by the number of times each coil of wire on the armature passes completely through a magnetic field of force. If a single coil is moved completely through the magnetic field once each second, the current has a frequency of one cycle per second. If it is passed through the field ten times per second, the frequency is 10 cycles per second. The frequency of alternating current most commonly used in homes and factories in the United States is 60 cycles per second. For some purposes, however, A.C. of frequencies as low as 4 cycles per second and as high as 50 billion cycles per second have been used.

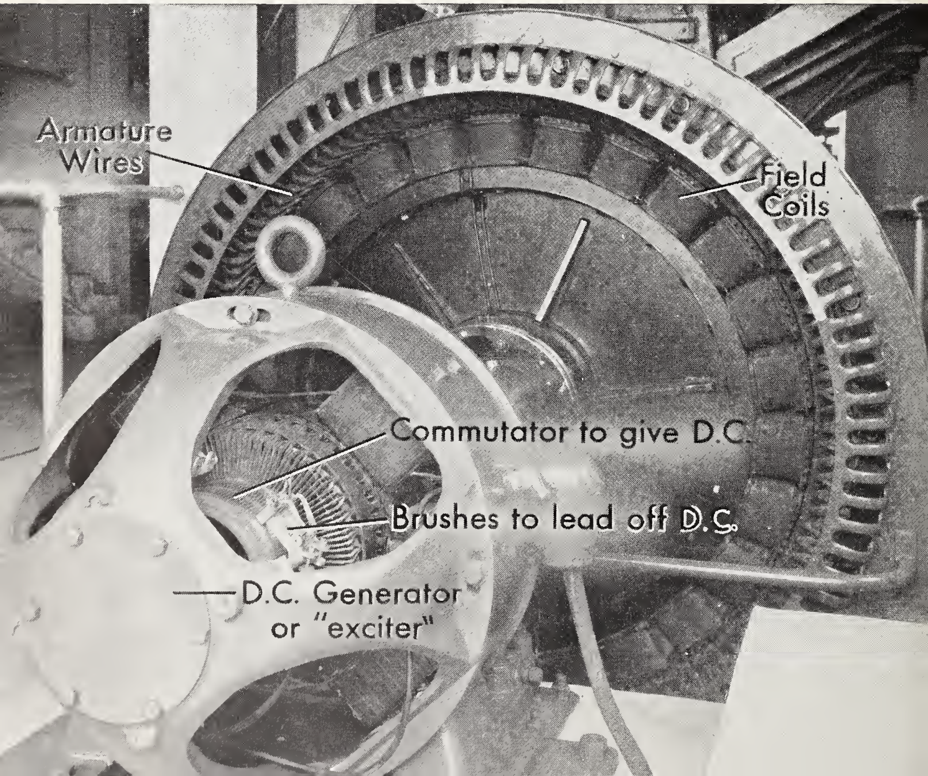
Some household appliances can be used only with alternating current or only with direct current. If you should move from one locality to another, you would be wise to find out in advance which kind of electric current is delivered to your new home and to see whether your appliances can be operated with it. Most appliances bear a small plate stating the kind of current to be used with them.

Alternating currents travel in a copper wire almost as fast as radiant energy travels in space. Yet the electrons in an alternating current move back and forth near one point in a conductor. How, then, can we explain the apparent high speed of A.C.? It is simply that what we call A.C. is a back and forth wave of electron motion as described on pages 153-154.

Like radiant energy, alternating current can be produced in varying amplitudes. The electrons move shorter distances each way at lower amplitudes than they do at greater amplitudes. The distance they move back and forth in the wire depends upon the strength of the electromotive force produced by the generator. This, in turn, depends upon the amount of the magnetic field through which the armature passes each second. For example, if the armature passes rapidly through the field, a stronger electromotive force will be produced than if it passes slowly through the field. The armature passes through more of the magnetic field per second when the field or the armature rotates rapidly than when it rotates slowly. Also, the more turns of wire

In this A. C. generator the field coils rotate and the armature is stationary. The D. C. generator makes the field coils strong electromagnets.

Westinghouse



on the armature or the stronger the magnetic field, the greater the electromotive force.

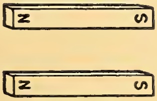
SUMMARY

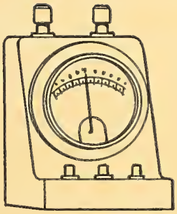
If large numbers of electrons are caused to collect upon materials which will not carry them away, static electricity is produced. Production of static electricity must be prevented in places where it would cause damage.

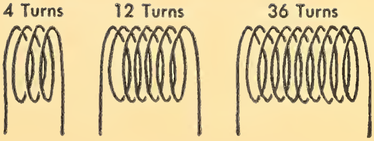
When electrons move through a conductor, such as a copper wire, they become an electric current. If the electrons move in only one direction, the current is direct. If they move back and forth, the current is alternating. Alternating-current electricity can be generated by passing conductors through magnetic fields, or moving magnetic fields past conductors.

Alternating currents have characteristics similar to those of radiant energy. That is, they vary in frequency and amplitude. The frequency of alternating current is determined by the speed at which the armature passes through a magnetic field. The amplitude is determined by the electromotive force, which depends upon the speed of the armature, the number of turns of wire on the armature, and the strength of the magnetic field through which it passes.

DEMONSTRATION







Generalizations to be demonstrated. 1. An electromotive force is produced in a conductor passing through a magnetic field.

2. The direction of the electromotive force depends upon the direction in which the conductor passes through the field.

3. The strength of an electromotive force can be varied by changing the speed with which the field is cut; by changing the strength of the field; and by changing the number of conductors passing through the field.

What you need. A galvanometer (an instrument to show small amounts of electric current); two bar magnets; several feet of insulated copper wire such as bell wire.

What to do. 1. Form a small coil of wire about 2 inches in diameter and made up of 12 turns of wire. Connect the ends of the coil to the galvanometer. Put one pole of the magnet inside the coil, and move the coil back and forth. Observe the action of the pointer on the galvanometer.

2. Move the coil over one pole of the magnet at three different speeds from very slow to fast, but always in the same direction. Observe the movement of the galvanometer pointer during each trial.

3. Place the two magnets next to each other with the like poles together, and move the coil back and forth over both of them. Observe the movement of the pointer. Repeat with unlike poles next to each other.

4. Form two additional coils of wire similar to the one used in step 1 above, but make one coil of 4 turns and the other of 36 turns. Move each of the coils in turn over one pole of the magnet, being careful to move them at about the same speed each time. Observe the movement of the pointer in each of the three trials.

What to observe. 1. How is the pointer on the galvanometer affected when the coil is moved through the magnetic field? How is the pointer affected when the direction in which the coil moves is changed?

2. What effect does strengthening the magnetic field, or putting two like poles together, have upon the movement of the pointer?

3. What effect does weakening the magnetic field, or putting two unlike poles together, have upon the motion of the pointer?

4. How do the number of turns of wire affect the movement of the pointer as the coil passes through the magnetic field?

What does it mean? 1. How do the observations you have made support generalizations 1, 2, and 3, as stated at the beginning of the demonstration?

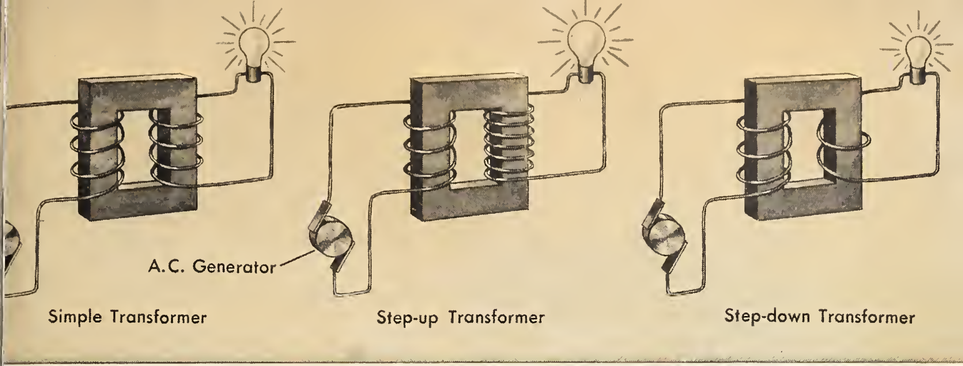
2. How are these generalizations used in constructing electric generators?

A basic assumption. An electromotive force in the coil causes the pointer on the galvanometer to move.

TEST YOURSELF

In the proper place on your answer sheet write the letter of the ending which best completes each statement.

1. The electricity most often used in homes in the United States is known as (a) static; (b) direct current; (c) alternating current; (d) high-frequency current.
2. When the electrons producing an electric current always move one way in the wire, the current produced is known as (a) alternating; (b) direct; (c) static; (d) high-frequency.
3. When a conductor is passed through a magnetic field, the field (a) produces an electric current in the conductor; (b) produces an electromotive force in the conductor; (c) has no effect on the conductor; (d) produces static electricity.
4. Static electricity (a) is used to operate generators; (b) is of little practical use; (c) is used for electroplating; (d) is used to operate some household appliances.



In each of these transformers, the primary coil is on the left, the secondary coil on the right. The step-up transformer, with more turns of wire on the secondary coil than on the primary coil, increases voltage in a circuit. The step-down transformer, with fewer turns on the secondary coil, decreases voltage.

PROBLEM 2. How is electricity distributed to our homes?

TRANSMISSION SYSTEMS

The electricity produced at a single power station is carried considerable distances from the station over a set of wires known as a *transmission system.* When it is sent over open country for great distance it is carried by *transmission lines* supported on high towers. The transmission lines are usually composed of three wires several feet apart. Because electricity can be transmitted at high voltages with little loss, the voltage of transmission lines is often more than 250,000 volts. Often one transmission line supplies the electricity for several small communities.

Substations. Before the electricity obtained over a transmission line can be distributed to users, the high voltage must be reduced to between 2,000 and 6,000 volts. This is done in a *substation* (see page 195) usually located in the outskirts of a community. Electricity at the lower voltage is then distributed through wires to all parts of the locality. But the voltage is still too high to be used in homes, and it has to be further reduced before the electricity enters the wires leading into the house.

Special devices called *transformers* are used to decrease or increase voltage. When they reduce the voltage in the transmission lines, they are called *step-down transformers.* When they increase voltage, they are called *step-up transformers,* which are used at power stations to increase the voltage produced by the generators before the electricity enters the transmission line.

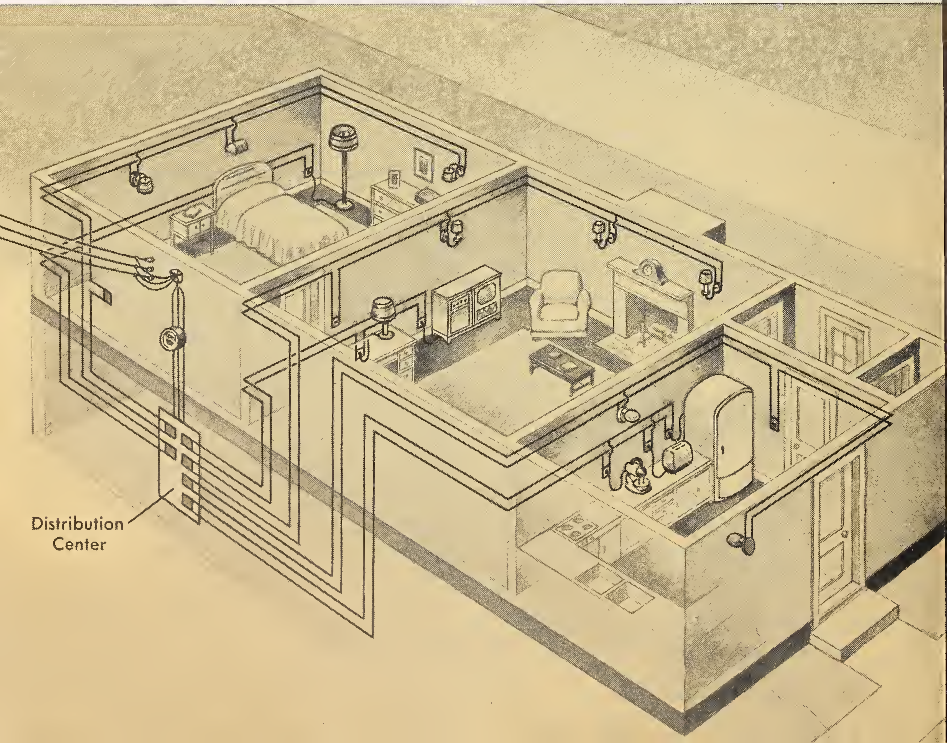
The wires and transformers that distribute electricity to the smaller and widely separated communities of the country are often suspended on tall poles. Such a system is unsightly, and the wires are often broken by storms. Broken wires not only disrupt the operation of the system but also are dangerous if touched. In larger cities, therefore, wires, transformers, and other equipment are put underground.

Transformers. A simple transformer (as shown on page 203) is composed of two coils of wire, a *primary coil* and a *secondary coil,* wound on an iron frame called a *core*. The wire making up the primary coil is not connected to the wire making up the secondary coil.

As you will recall, an electric current is the *movement* of electrons from one atom to another in the conductor. An electric current in a wire produces a magnetic field around the wire. Therefore, an electric current in the primary coil of the transformer produces a magnetic field. This magnetic field causes the iron core to become a magnet. A magnet produced by an electric current is called an *electromagnet*. The electromagnet in turn has a magnetic field. Since the wires making up the secondary coil are wound on the same iron core as those of the primary coil, they are in the magnetic field of the electromagnet produced by the primary coil.

In the transformer, each time the electrons in an alternating current move back and forth in the primary coil, a magnetic field of force, acting first in one direction and then in the opposite, is produced around the iron core. Each time the magnetic field is reversed in the core, it sweeps back and forth across the wires of the secondary coil. Thus, in effect, the wires

This diagram shows how electricity is distributed to all parts of a home. Entering by the three overhead wires, it passes through the meter to the distribution center. Several parallel circuits are used to distribute the electricity throughout the house to prevent overheating of the wires.



are cutting magnetic lines of force, and an alternating electromotive force is produced in them. In this manner, A.C. in the primary will produce an alternating electromotive force in the secondary which will cause A.C. in any suitable appliance connected to the secondary. A current of electricity produced by magnetism, as in the secondary coil of the transformer, is called an *induced current.* If the number of turns of wire in the primary coil is the same as that in the secondary coil, as is true in the simple transformer shown on page 203, the voltage induced in the secondary coil is the same as that in the primary coil.

A transformer that has more turns of wire in the secondary coil than in the primary coil (see drawing on page 203) increases, or "steps up" the voltage of the secondary coil and is therefore called a step-up transformer. A transformer that has fewer turns of wire in the secondary coil than in the primary coil (see drawing on page 203) reduces, or "steps down" the voltage of the secondary coil, and is therefore called a step-down transformer. The use of step-up and step-down transformers in the electric distribution system makes it possible to change the voltage to any amount desired.

HOUSE DISTRIBUTION SYSTEMS

The electricity is brought by wires from the main distribution lines to a place inside a house or other building which serves as a distribution center. It is then carried to various parts of the building by several pairs of wires, each pair of wires forming a small distribution system called a *circuit.* Each circuit provides electricity for only one part of the house.

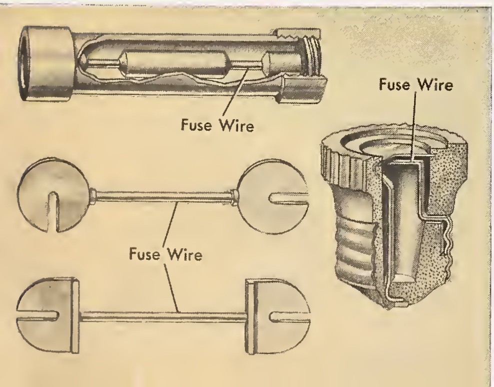
Follow the path of the electricity from the socket through each lamp and back into the socket. All of the electricity must pass through every part of the circuit in this series wiring.

Series and parallel wiring. Electric circuits can be wired in one of two ways, either in *series* or *parallel.* The lamps on the Christmas tree shown above are wired in series. As you can see, all the electricity in the circuit must flow through each lamp. Therefore, if the filament in one lamp breaks, the electricity can no longer continue through the circuit. This is true of all circuits wired in series. It is clear that such wiring would be unsatisfactory for our homes, for when one electric device was turned off, the circuit would be broken and none of the other appliances on the circuit would be able to operate. Houses are therefore wired in parallel circuits, as shown on page 204. You will note that in parallel circuits only the electricity required to operate a particular appliance reaches it. Each appliance can therefore be switched off or on without affecting the operation of any other one.

Safety features in house wiring. When a circuit carries too much electricity, the wires may become hot enough to cause a fire. If the two wires making up a circuit touch each other, there is so much current in the circuit that it becomes overheated. Such a condition is called a *short circuit*. Short circuits in a house wiring system are prevented by use of wires covered with some insulator, such as rubber, which does not conduct electricity. To prevent the insulation from wearing off, the wires may be encased in metal tubes.

The cords that connect appliances such as toasters, radios, and refrigerators to the house wiring circuit must also be insulated to prevent not only short circuits, but also shock to the user of the appliance. In handling any electric appliance, the user should be careful to avoid breaking or tearing the insulation on the cord. To remove the cord from an outlet, pull on the plug attached to the end; never pull on the cord itself. A cord on which the insulation is worn should be repaired or replaced as soon as possible.

Fuses are placed in each circuit at the distribution center. The different shapes and sizes allow larger or smaller amounts of current to pass without breaking the circuit. A burned-out fuse should be replaced only with another fuse designed to carry the same amount of current.



An ordinary house wiring circuit may become dangerously overheated if too many appliances are used at the same time. For example, if a refrigerator, coffee maker, iron, radio, and toaster were connected to one circuit and operated at the same time, they would require more electricity than most house circuits are designed to carry. The wires would become overheated, and there would be danger of fire. Protection against such accidents is provided by *fuses*.

Fuses contain a strip of metal which will melt at a low temperature. If too much electricity flows through the circuit, the metal strip becomes hot and melts, thus breaking the circuit so that the current can no longer pass through it. The fuse thus prevents the circuit from becoming overheated by short circuits or by the operation of too many appliances at one time.

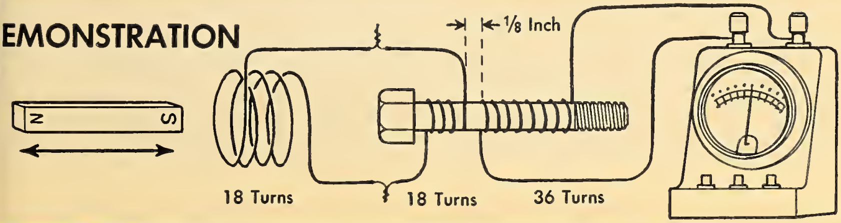
To insure safety, the electric wiring in a house must be installed properly. There should be enough circuits of large enough wire to keep heat losses low, so as to operate safely all the electric appliances that are likely to be used. Rules for safe wiring, prepared by the National Board of Fire Underwriters, are called the *National Electric Code,* and should be followed in wiring homes. All electric wiring should, therefore, be done by competent electricians. Most cities require that the wiring systems of new houses be inspected before they can be occupied.

SUMMARY

Electricity is made available for use in our homes through three different distribution systems. Because of the great distances over which it must be sent, electricity is transmitted from the power station over high-voltage transmission lines to community substations. In the substation, the voltage is reduced, and the electricity is distributed through another system of wires to homes in the locality. At the homes the voltage is again reduced and the electricity is distributed to each electric outlet through a system of house wiring circuits. Transformers are used to change the voltage of electricity in the different distribution systems.

In order that house wiring systems may be safe, they should be properly installed. Enough circuits should be provided to supply adequate current to operate lighting fixtures and electric appliances in the home. Fuses protect electric circuits in the home from carrying more current than they are designed to carry safely.

DEMONSTRATION



Generalization to be demonstrated. Whenever an alternating current passes through the primary coil of a transformer, an electromotive force is produced in the secondary coil.

What you need. A magnet; several feet of insulated copper wire; a large iron nail, such as a spike, or a bolt; a galvanometer.

What to do. Set up the equipment, as shown in the drawing above. Then move one pole of a magnet back and forth through the center of the coil attached to the primary coil of the transformer, and observe the action of the galvanometer pointer.

What to observe. How does the movement of the magnet through the coil affect the pointer of the galvanometer? What evidence is there that an electromotive force is being produced?

What does it mean? 1. How does the movement of the pointer of the galvanometer give evidence to support the generalization being demonstrated?

2. How does this generalization help explain the action of the transformer used in electric distribution systems?

Basic assumption. What is one basic assumption that must underly this demonstration?

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. A device used to increase or decrease voltage is (a) a transformer; (b) a generator; (c) an insulator; (d) a conductor.
2. The voltage is usually highest in the (a) house circuit; (b) distribution system; (c) transmission system; (d) A.C. generators.
3. If a transformer has fewer turns of wire on the secondary coil than on the primary coil, it will (a) raise the voltage; (b) lower the voltage; (c) not change the voltage; (d) get hot.
4. House wiring circuits are (a) series circuits; (b) short circuits; (c) parallel circuits; (d) open circuits.
5. The device which protects the house wiring circuits against overloads is a (a) fuse; (b) transformer; (c) meter; (d) generator.

CHAPTER ACTIVITIES

REVIEW YOUR UNDERSTANDING

Following is a list of the various parts of an electric production and distribution system. On your answer sheet, write the number of that part which comes first, then second, then third, and so on, as you trace the electricity from its source to your home. **Do not write in this book.**

1. Transmission line
2. Alternating current generator
3. Distribution line
4. Small step-down transformer
5. Substation
6. Large step-down transformer
7. Large step-up transformer

SELECT SOURCES OF INFORMATION

Bill saw an article in the newspaper which stated that a new substation to cost $150,000 was being built in his home town. The new substation would, when finished, provide the city with much better electric service. There was also a picture of the partly completed substation. Bill wondered just what a substation was for and how it helped improve electric service so much that the electric company was willing to spend that amount of money to build it. He decided to find out as much as he could about the substation and its purpose.

On your answer sheet, write the letters of each of the following sources of information which you think Bill might profitably use.

a. Visit the site of the substation and talk with people who live near it.
b. Ask his science teacher.
c. Look in an encyclopedia.
d. Talk with the manager of the electric light company.
e. Ask his brother who had just finished a course in business administration in college.

Ewing Galloway

A view of part of New York City taken at night from the top of the Empire State Building emphasizes a city's dependence upon electricity.

chapter 11 USING ELECTRICITY

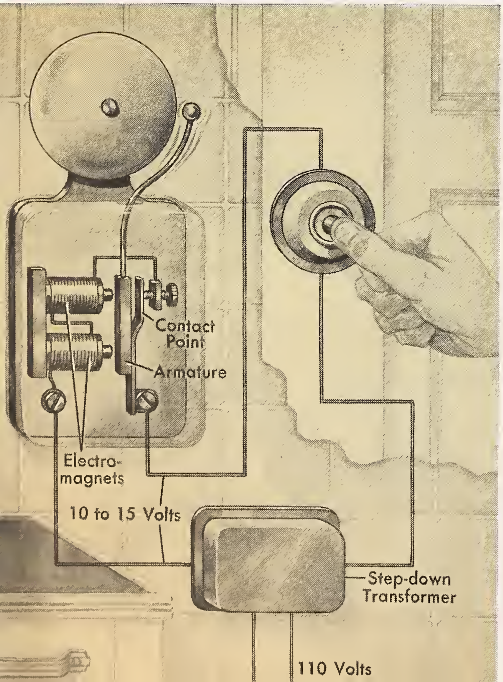
WE HAVE all used electricity for a great many different purposes in our homes. But actually electricity is used in only two general ways, namely, to produce heat and to operate machines. It produces heat in the electric light bulb, the electric stove, the toaster, the heating pad, and the electric blanket; and it operates such appliances as the vacuum cleaner, the washing machine, the sewing machine, the food-mixer, and the door bell. How is it possible for electricity to produce heat in some household appliances and to run things in others?

PROBLEM 1. How is electricity used in our homes?

ELECTRICITY FOR HEAT

Heat produced in conductors. As we know, when too much electricity flows through a conductor in an electric circuit, the conductor may become overheated. The heating is due not only to the amount of electricity flowing through the conductor but to the *resistance* the electricity meets as it flows. You will remember that electricity is believed to be the transfer of free electrons from atom to atom in a conductor. The atoms in the conductor *resist* the transfer of electrons. This characteristic of conductors is known as *resistance*. Overcoming the resistance to the transfer of electrons from one atom to another produces the heat in a conductor. Conductors vary in the extent to which they resist the transfer of electrons. The electrons of silver atoms, for example, are held more loosely than those of any other metal. Silver therefore has the lowest resistance of all the metals and is heated least as electricity flows through it.

As the button is pushed, electricity flows through the electromagnets. They pull the armature to them, which pulls the contact points apart. Electricity then stops, the contact points touch again, electricity flows, they are again pulled apart. This process continues while the button is pushed.



The resistance of conductors is measured in units called *ohms*. The resistance of several kinds of wire, each one foot long and one-thousandth of an inch in diameter, is given below:

Metal	*Ohms*
Silver	9.9
Copper	10.4
Aluminum	17.0
Tungsten	35.8
Zinc	36.7
Iron, commercial	72.84
Nichrome	660.0

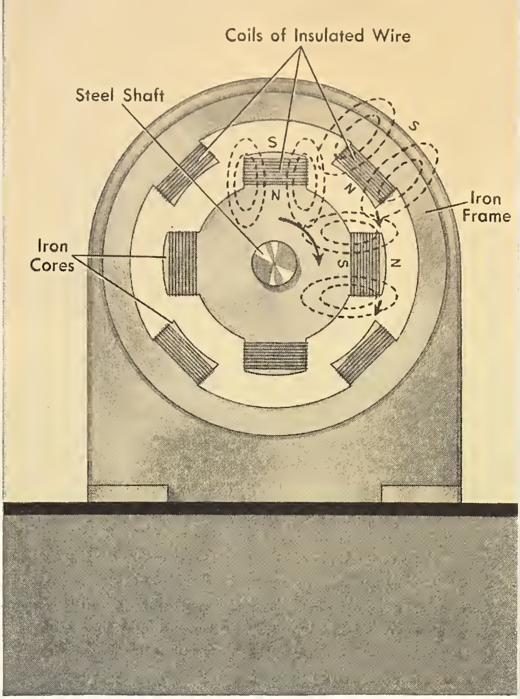
Since the heat in a conductor is produced by the overcoming of the resistance of atoms to the transfer of electrons, the more electrons that move each second, the greater the amount of heat in the conductor. Thus increasing the flow of electrons through a conductor increases the amount of heat produced in it. The number of electrons flowing through a conductor is measured in units called *amperes*. Try to imagine that you are looking inside a piece of wire watching individual electrons moving past a given point. When they pass the point at the rate of about six billion billion each second, the amount of electric current flowing in the wire is one ampere.

Heat-producing appliances in the home. Many of our electric appliances are designed to produce heat for various purposes. Each of these appliances contains a *heating element*. In the electric toaster, for example, the heating element is the wire that becomes red when the toaster is in operation.

The heating element of many electric appliances is made of a special material called *nichrome,* whose resistance, compared with that of other metals, is very high (see table, page 210). Electrons passing through nichrome wire in sufficient numbers produce heat enough, as they overcome its high resistance, to make the wire get red hot. The cord connecting such an appliance to the electric outlet does not become hot, however, because the wire in it is made of copper. Copper has a very much lower resistance than nichrome. Thus the amount of current which causes the nichrome to become extremely hot produces only a small amount of heat in the copper wire.

Electric ranges, waffle irons, and hot-water heaters must be heated to high temperatures to serve their purposes. Electric blankets and heating pads, on the other hand, operate at low temperatures. By controlling both the resistance of the heating element and the amount of current flowing through it, the desired amount of heat can be produced in the device.

Home appliances operated by electromagnets. One of the simplest devices operated by an electromagnet is the door bell. The ordinary door bell is made to operate on from 10 to 15 volts. Since the electricity entering the house is generally 110 volts, it is reduced to the required voltage by a small step-down transformer. Its operation is explained on page 210.



The coils in some electric motors are placed so that their magnetic fields push and pull each other, causing the armature to turn. As it turns, the fields are changed, thus providing a steady turning force.

Electromagnets are also used to operate electric motors. In construction, an electric motor is similar to an A.C. generator. Like the generator, it has a field and an armature. The field consists of a number of electromagnets, and does not move. The armature rotates. Two types of armatures are used. In one type, a number of coils of wire are wound around the core. In the other type, many short pieces of a good conductor, such as copper, run lengthwise on a core shaped like a cyclinder. When electricity passes through the motor, the coils on one type and the copper strips on the other type become strong electromagnets.

General Electric

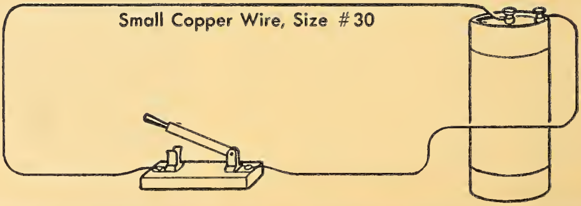
An electric blanket with automatic control adds comfort in cold climates.

As you will recall, magnets have a north pole and a south pole. The unlike poles attract each other and the like poles repel each other (see drawing, page 145). In an electric motor, the electromagnets are wired and arranged so that each armature magnet is being pulled and pushed by electromagnets of the field. Thus a north pole on the armature has a south pole just ahead of it and a north pole just behind it in the field. If the poles of the electromagnets on the armature and the field always remained the same, it would not be possible to continue the pushing and pulling effect necessary to keep the armature moving. The poles of the electromagnets on either the armature or field of an electric motor are constantly being changed as the motor operates. Thus electric current is sent through the armature or the field so that many magnetic forces are pulling or pushing on the armature to keep it turning. Electric motors use electricity to run such appliances as food mixers, vacuum cleaners, washing machines, refrigerators, stokers, and some oil burners.

SUMMARY

Electric home appliances depend upon either the heating or the magnetic effect of an electric current. The heating effect is produced by electrons overcoming the resistance of a conductor to their passage through it. The magnetic effect is caused by the magnetic field that is produced when electrons move through a conductor. Equipment designed to control these two effects makes it possible for us to use electricity for many purposes in our homes.

OBSERVATION

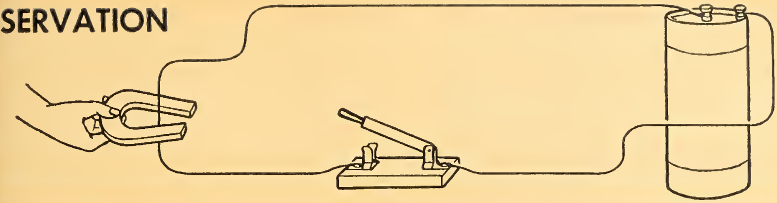


What to observe. The heating effect of electricity.

How to observe it. Set up the equipment, as shown above. Watch the small wire as you close the switch.

Interpretation of observation. In one sentence, state what happens when electricity from a dry cell passes through a small copper wire.

BSERVATION



What to observe. The action of the force that runs an electric motor.

How to observe it. Arrange the equipment, as shown above. Be sure the wire is free to move. Watch the wire near the magnet as you close the switch for an instant. Reverse the connections to the dry cell, and again close the switch while watching the wire.

Interpretation of your observation. 1. State what happens to the wire as the switch is closed.

2. What is the effect of reversing connections to the dry cell?

TEST YOURSELF

In the proper place on your answer sheet write the letter of the ending which best completes each statement.

1. The tendency of atoms to resist transferring free electrons accounts for a conductor's having (a) resistance; (b) weight; (c) color; (d) strength.
2. Among these four materials, the one with the lowest resistance to flow of electricity is (a) nichrome; (b) copper; (c) silver; (d) zinc.
3. When electricity overcomes the resistance of a conductor, the result is the formation of (a) magnetic fields; (b) heat; (c) sound; (d) rust.
4. To obtain the proper voltage for an ordinary electric bell from the house circuit, it is necessary to use (a) a step-up transformer; (b) a step-down transformer; (c) a push button; (d) an electric motor.
5. Electricity flowing in a conductor makes an electric motor run because it produces (a) heat; (b) magnetism; (c) sound; (d) radio waves.

PROBLEM 2. How is the electricity we use measured?

UNITS OF MEASURE

Electricity is invisible. It also seems to have no weight, nor can it be collected in any type of container. How then can it be measured? It must be measured by indirect methods.

We have learned that when electricity passes through a conductor, a magnetic field is produced. The strength of this magnetic field increases or decreases according to the amount of electricity that passes through the conductor. Therefore, if we can measure the strength of the magnetic field, we can also measure, indirectly, the amount of electricity that is flowing in a conductor to produce it. This is the most common method of measuring the amount of the flow of electricity. Other effects, such as the heat produced by an electric current, can also be used.

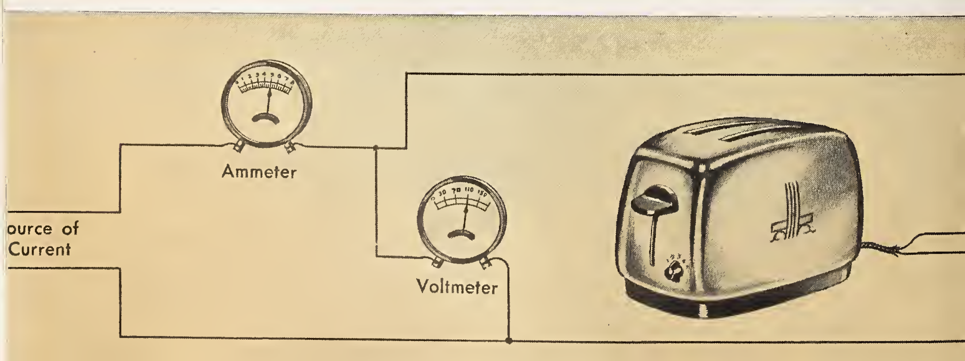
Relationships among units of electrical measurement. As you will recall, the three fundamental units used in measuring electricity are the volt, the ampere, and the ohm. The volt is the unit used in measuring the electromotive force which causes electrons to move in a conductor. The ampere is the unit for measuring the number of electrons that flow past a point in one second of time; that is, it is a measure of the rate of flow of electricity. The ohm is the unit used to measure the resistance offered by a conductor. These units used in measuring electricity are closely related to one another, since one volt causes a current of one ampere when overcoming a resistance of one ohm.

Instruments for measuring volts and amperes. The number of volts, or the voltage, across an electric circuit is measured by the *voltmeter*; and the current in a circuit, that is, the amperes, is measured by the *ammeter*. The ending of these words, *meter,* comes from a Latin word meaning "to measure." Most of the names of measuring instruments therefore end in "meter." There are two types of voltmeter and two types of ammeter, one for use with alternating current, the other with direct current.

Ohm's Law. The results of experiments have shown that the resistance of an electric circuit is equal to the number of volts divided by the number of amperes. The way this rule is used can be seen below. This relationship between volts, ohms, and amperes exists in all electric circuits. It is known as Ohm's Law because it was first recognized in 1827, after considerable experimentation, by George Simon Ohm. Scientists express it by saying that the current in amperes in all D.C. circuits and in some A.C. circuits is equal to the voltage of the circuit divided by the resistance of the circuit.

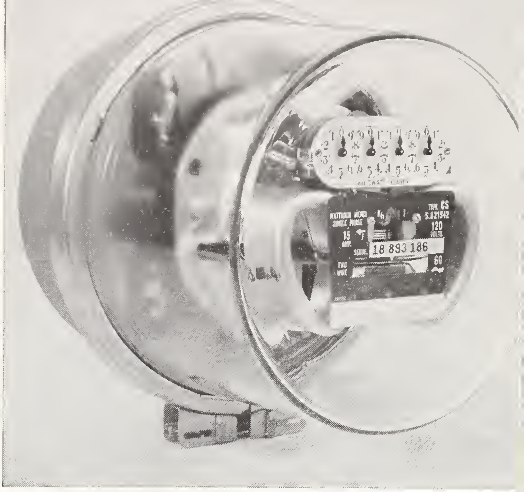
Measuring amount of electricity used. If you will examine some of the electric appliances in your home, you will probably find a small plate containing a number followed by the word *watts.* The watt, named for the Scottish scientist James Watt, is the unit used to measure how fast an electric appli-

If, when an electric current is passed through this circuit, the voltmeter registers 110 volts and the ammeter 5 amperes, the resistance of the toaster can be determined by dividing voltage, 110, by amperage, 5; that is, the resistance is 22 ohms.



ance uses electricity. The electric lamps used in our homes range from 25 to 300 watts. A 300-watt lamp would use electricity about 12 times as fast as a 25 watt lamp.

The total amount of electricity used by any electric appliance depends not only upon how fast it uses electricity but also upon the length of time it is operated. It takes more electricity to operate an electric iron for one hour than for only thirty minutes. When a large amount of electricity is used for all purposes in the home, the electricity is measured in kilowatts. The kilowatt is 1,000 watts, the prefix *kilo* meaning 1,000. For a definite period of time, such as a month, it is measured in *kilowatt-hours.* A kilowatt-hour means that 1,000 watts are used for one hour. Kilowatt-hours are recorded by an electric meter (shown at right). If an electric hotplate using 1,000 watts is operated for one hour, the electric meter will register one kilowatt-hour of electricity. It will also show one kilowatt-hour if a 100-watt electric lamp is used for 10 hours. In other words, the number of watts multipled by the number of hours and divided by 1,000 will give the kilowatt-hours of electricity used. If you know the price you pay for one kilowatt-hour of electricity, you can easily estimate how much it costs to operate many of the electric appliances in your home. Some of the exercises at the end of this chapter will help you to learn to figure the cost of operating various electric appliances.



Westinghouse

In the watt-hour meter, a wheel turns in a magnetic field with a speed dependent upon the amount of electricity being used. It causes the four pointers to register the kilowatt-hours.

SUMMARY

We can measure electricity indirectly by observing its magnetic or heating effect as it flows through a circuit. The current in amperes in an electric circuit is determined by dividing the voltage by the resistance of the circuit. Electricity required to operate light fixtures and appliances in our homes is measured in kilowatt-hours. Meters are connected with house wiring systems to measure the total amount of electricity used during a definite period of time.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words on your answer sheet which should be substituted for the *italicized* ones to make it true.

1. One common way to measure electricity is to measure the *magnetic* effect which it produces.
2. If a 100-watt light bulb is lighted for ten hours, it will use *1,000* kilowatt-hours of electricity.
3. If a circuit has 110 volts across it and 5 amperes of current in it, the resistance is *550* ohms.

PROBLEM 3. How is direct-current electricity used?

PRODUCTION OF DIRECT CURRENT

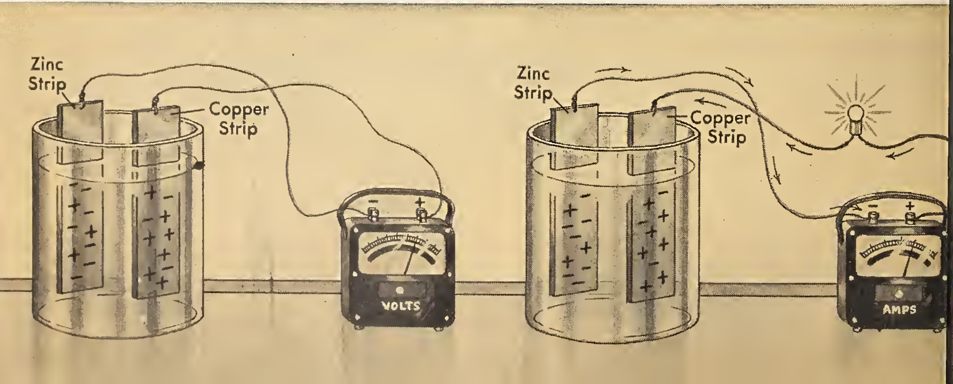
Direct-current electricity is similar to alternating current in a number of ways. It is measured with the same units, namely, the volt, the ampere, and the watt. The resistance of wires to direct current is also measured in ohms. Like alternating current, direct current in a conductor produces heat and magnetic fields. Whereas in alternating current the electrons are constantly reversing their direction of motion, in direct current they always move in the same direction. This fundamental difference between the two kinds of current is accounted for by the way in which direct current is produced. The difference also explains why direct current can be used for certain purposes for which alternating current is unsuitable.

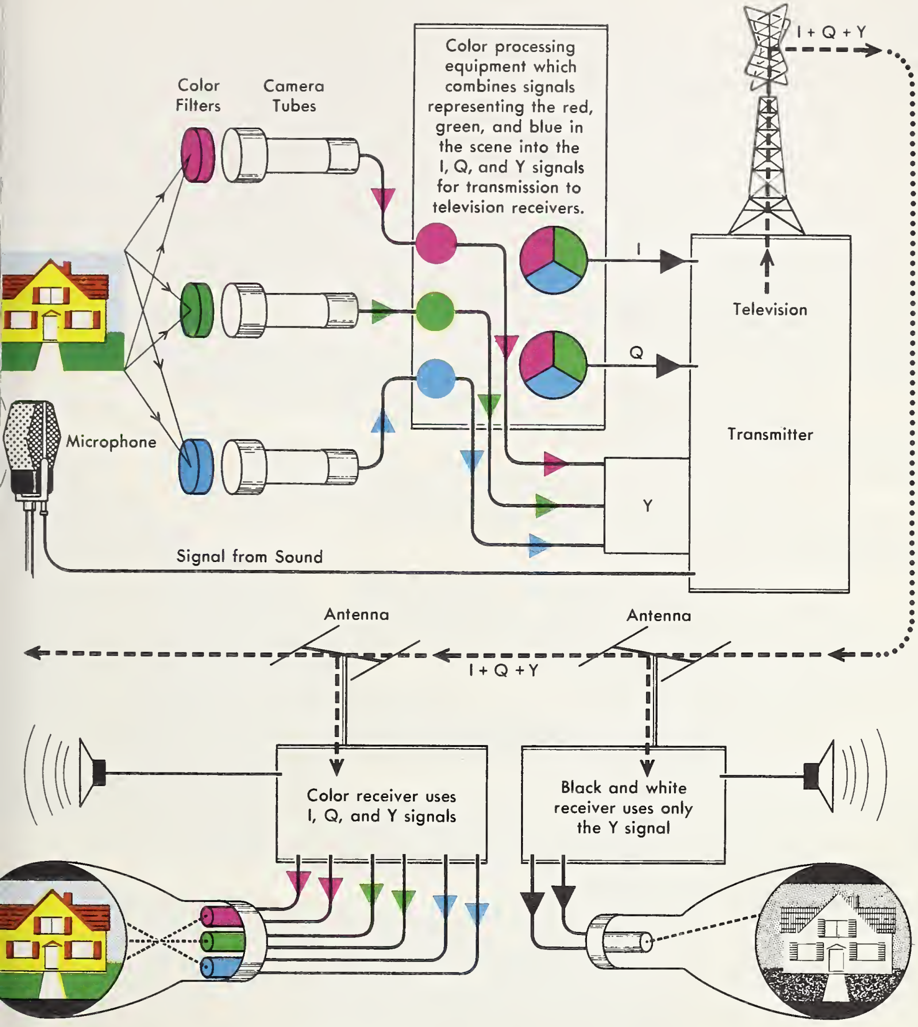
Producing direct current by chemical action. The chemical action that takes place when zinc (Zn) and copper (Cu) are put in sulfuric acid (H_2SO_4) is such that the zinc (Zn) becomes negative with respect to the copper (Cu). A voltmeter will show an electromotive force of about 1 volt (see drawing below). The zinc (Zn) is called the *negative terminal,* while the copper (Cu) becomes the *positive terminal.* A device to produce an electromotive force by chemical action is commonly called a *cell.*

An ammeter and a suitable electric lamp connected in series as shown (see below) would indicate a current in the circuit. The current results from the electromotive force existing between the metal strips. Since the electromotive force is steady there is direct current in the circuit.

You may read in some books the statement that electricity flows from the positive to the negative pole. For many years this was thought to be true, and the practice of referring to electricity as flowing from positive to negative has become so well established that it is still used, even though it is now known to be incorrect. *In this book all explanations are based on the fact that since an electric current is a movement of electrons, it must travel*

If a zinc strip and a copper strip are placed in a glass jar containing dilute sulfuric acid and are then connected to a voltmeter, as shown at left, the voltmeter will register about 1 volt. If a lamp of proper size is wired as shown at right, the voltage will force the current through the circuit and light the lamp.

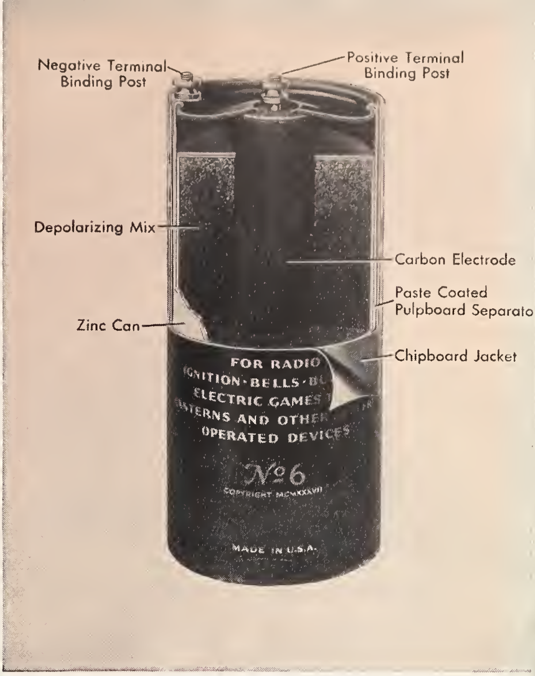



Color Filters
Camera Tubes
Color processing equipment which combines signals representing the red, green, and blue in the scene into the I, Q, and Y signals for transmission to television receivers.
I + Q + Y
I
Q
Television
Transmitter
Y
Microphone
Signal from Sound
Antenna
Antenna
I + Q + Y
Color receiver uses I, Q, and Y signals
Black and white receiver uses only the Y signal

In color television broadcasting, light reflected from the illuminated scene passes through color filters on its way to the camera tubes. Thus the signal from the top camera tube depends upon the red in the scene; that from the middle camera tube depends upon the green; while the lower camera tube produces a signal depending upon the blue in the scene. The I and Q signals depend primarily upon the different *colors* in the scene while the Y signal depends upon the *brightness* of the colors. Thus while the Y signal (brightness) alone will operate a black and white receiver, all three signals are needed to operate a color receiver.

Courtesy Johnson's Wax

These light fixtures, placed between walls of glass tubes, give light without shadow inside this modern building. The use of science made this desirable effect possible.



National Carbon Company, Inc.

In a dry cell, the negative terminal is a zinc can and the positive terminal is a carbon rod. These are separated by a moist mixture of chemicals. When the terminals are connected to a circuit, chemical action in the dry cell produces a voltage which causes current.

from the negative to the positive terminal of a cell.

The cell just described is seldom used for practical purposes because it has two disadvantages. First, the chemical action of the sulfuric acid on the zinc is so rapid that it soon dissolves the zinc. Second, the cell cannot well be moved from place to place because the acid is easily spilled. To overcome these difficulties, a more practical cell, the *dry cell,* has been developed and is now in general use.

The dry cell. The construction of a dry cell is shown at the right. Dry cells are made in several sizes and shapes for use in portable radios, flashlights, electric toys, and in some gasoline engines. Regardless of size or shape, a dry cell of this type always produces an electromotive force of about 1.5 volts. If more than 1.5 volts is needed, several cells are wired together in series, as shown on page 219. Such a group of cells is called a *battery.* The total voltage of such a battery is found by multiplying 1.5 by the number of cells. For example, if the cells in a three-cell flashlight are connected in series, the total voltage is 4.5 volts.

Dry cells are sometimes connected in parallel, as shown on page 219. The voltage of a battery of cells so connected is the same as that of a single cell. After dry cells have been used for some time, the chemical change is completed; then the cells no longer produce an electromotive force and are useless.

Storage cells. There is a cell, the *storage cell,* that can be renewed after it no longer furnishes electricity. One type of storage cell consists of two lead plates in dilute sulfuric acid, and operates as shown on page 220. It can be *recharged* by being connected for a time with a source of direct-current electricity. Thus a storage cell, unlike a dry cell, can be used over and over again.

Storage batteries. The storage battery commonly used in automobiles is known as a *lead-acid* battery because the cells are lead plates covered with sulfuric acid. Each cell develops about 2 volts, and there are either 3 or 6 cells connected in series. Batteries are often rated in ampere-hours. An 80 ampere-hour battery will furnish about 1 ampere for 80 hours or 8 amperes for 10 hours.

Lead-acid batteries should be examined regularly. They should be kept clean. Some vaseline or grease on the terminals will keep them clean for some time. When the acid solution drops below the top of the plates, *distilled water only* should be added. The battery should not be charged too rapidly, nor ever allowed to become fully discharged.

Two other types of storage cells are shown on page 221. These cells are more rugged than lead-acid cells and can be completely discharged with less damage. However, the voltage of each is lower than the lead-acid, so that more cells are required for a battery of the same voltage.

Besides being used widely in automobiles, storage batteries serve much the same purposes in airplanes. They are also used as a source of power for some trucks, small tractors operated inside buildings, and submarines. Where it is not convenient to obtain electricity from other sources, they may be used to furnish the electricity for homes.

Generators for direct current. The generators that produce direct current are similar to those that produce alternating current. They consist of coils of wire whirling in a magnetic field. They must also have a device called a *commutator* that causes electricity to flow always in the same direction rather than to alternate back and forth. Direct-current generators are used to charge the batteries of automobiles as the car runs.

USES OF DIRECT CURRENT

Electroplating with direct current. It is often desirable to give a metal object a thin coating of another metal to make it either more beautiful or more durable. A brass spoon, for example, is more attractive to the eye when it is covered with silver (silver-plated). Type metal may be plated with nickel or chromium to protect it against wear in the printing process. Automobile parts, such as head lamps and bumpers, are plated with chromium, which improves their appearance and prevents the metal underneath from rusting.

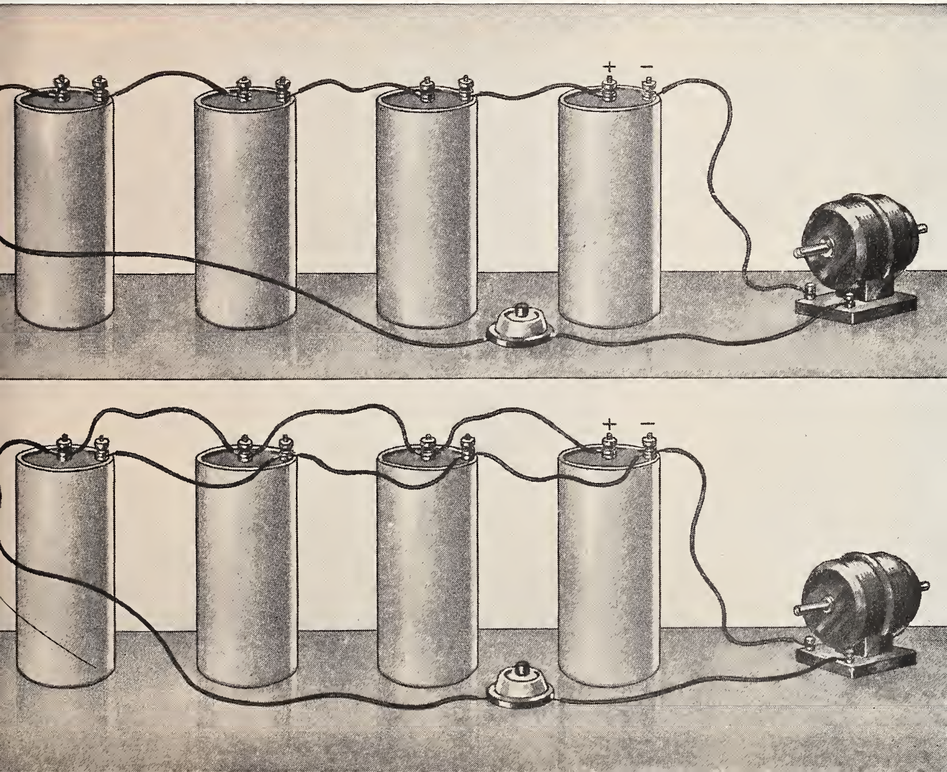
The process of plating one metal with a thin layer of another is called *electroplating*. It is usually done only with direct-current electricity. Let us suppose that a lead strip is to be plated with copper. The lead strip is connected to the negative terminal of a source of direct current, such as a dry cell, and a strip of pure copper is attached to the positive terminal. Both strips are then placed in a solution of copper sulfate and water. Immediately electricity begins to flow through the solution, and as it does so, copper is deposited on the lead strip.

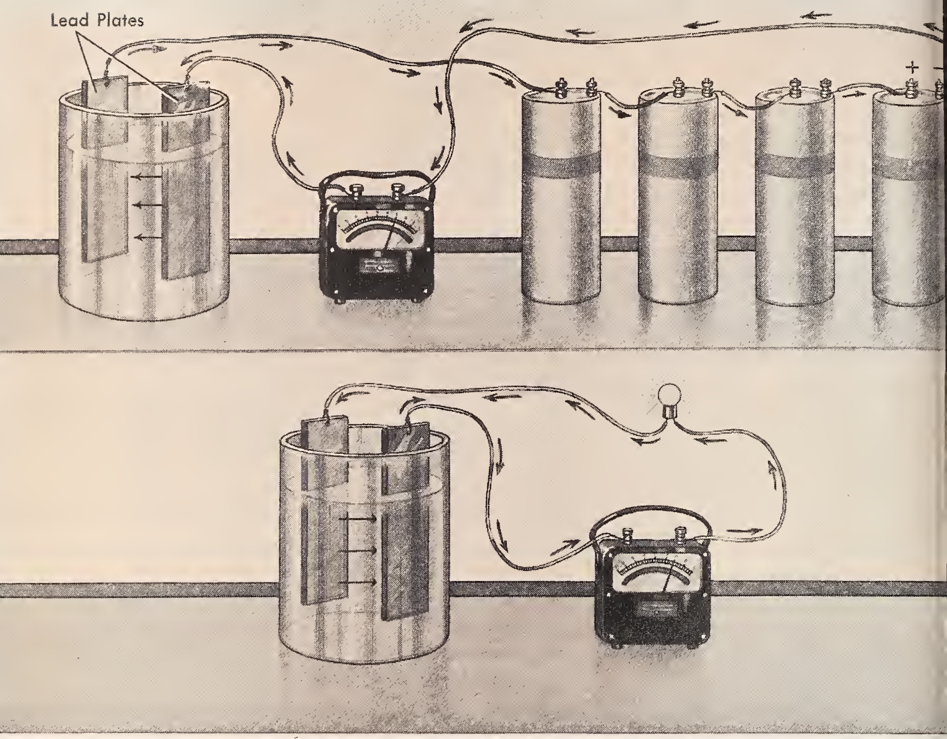
Other uses. Direct current can also be used in many of the same ways as alternating current. Any heat-producing appliance ordinarily used with alternating current can safely be used with direct current if the voltage is the same. Appliances operated by electric motors, however, must have a motor designed specially for the kind of current to be used. The starter in an automobile, for example, is an electric motor designed to be used with direct current from a storage battery. It cannot, therefore, be used with alternating current. Electric clocks, on the other hand, because their motors are constructed for use with alternating current, cannot be used with direct current. Electric clocks in automobiles, however, are designed to operate with direct current. Some radio sets are made to operate with either direct or alternating current, whereas others can operate only with alternating current. Any appliance containing an electric motor may be severely damaged if connected to the type of current for which it was not designed. Direct-current electricity is also used in extracting some metals from their ores. The process will be explained in Unit Thirteen.

SUMMARY

Direct-current electricity produces the same magnetic and heating effects as alternating current and can therefore be used for the same general purposes. Direct current can be produced by generators and by chemical change. The production of direct current by chemical change makes it readily available from batteries or dry cells or storage cells in situations where it would not be practical to obtain alternating current. Direct current is the only type of electric current that can be used in such commercially important processes as electroplating and the extraction of certain metals from ores.

(The dry cells are in series when center pole (+) is connected with an outside pole (−). They are in parallel when all center poles, and all outside poles, are connected together. The voltage across the motor is four times that of a single cell when they are in series and equals that of a single cell when they are in parallel.





A simple lead-acid storage cell. As electricity from the dry cells flows through the storage cell a brown chemical (lead peroxide) is formed on one plate (top). The cell is now charged and has a voltage of about 2 volts. The charged cell will now furnish electricity as it discharges (bottom). A storage cell can be charged and discharged many times.

TEST YOURSELF

In the proper place on your answer sheet write the letter of the ending which best completes each statement.

1. The chief difference between alternating and direct current is (a) the amount of heat produced; (b) the way the electrons move; (c) the amount of magnetic field produced; (d) their speed.
2. An electric cell is a device for producing electricity (a) by chemical action; (b) with magnetism; (c) with light; (d) with heat.
3. The center terminal of a dry cell is (a) negative; (b) zinc; (c) positive; (d) copper.
4. If six dry cells were connected in series, their total voltage would be (a) 1.5; (b) 6; (c) 9; (d) 18.
5. Storage cells are widely used because they (a) are durable; (b) can be recharged; (c) furnish alternating current; (d) are more easily manufactured.

CHAPTER ACTIVITIES

REVIEW USES OF ELECTRICITY

A number of the common uses of electricity are listed below. On your answer sheet, write a number for each use. After each number tell whether such use depends upon its heating, magnetic, or chemical effect.

1. Toasting bread
2. Plating silverware
3. Running a washing machine
4. Operating a door bell
5. Percolating coffee
6. Cooking waffles
7. Operating a bicycle light
8. Operating the starter in an automobile
9. Igniting dynamite for blasting
10. Welding steel

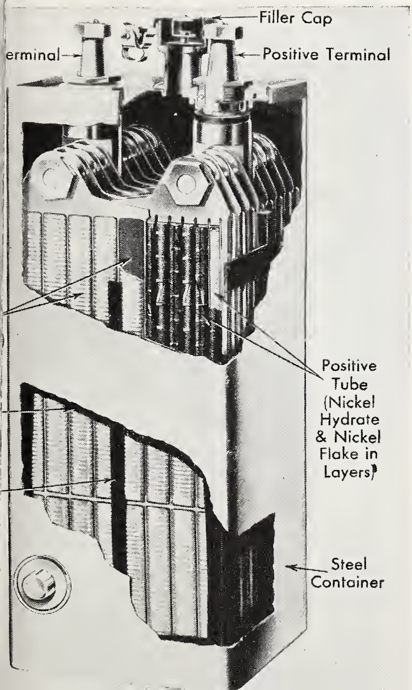
SOLVE MATHEMATICAL PROBLEMS

Solve each of the following problems and place the correct answer in the proper place on your answer sheet.

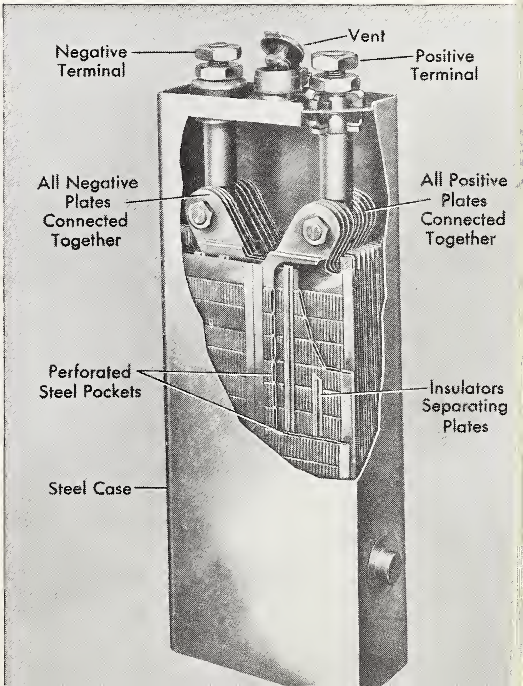
1. If an electric lamp having a resistance of 40 ohms is connected across 80 volts, how much current (amperes) will there be in the bulb?

At left is an iron-nickel storage cell. The steel positive pockets are filled with nickel-hydrate and nickel flake; the negative pockets contain iron oxide. The plates are covered with a solution of potassium hydroxide. At right is a nickel-cadmium storage cell. Pockets in the steel positive plate are filled with nickel hydroxide and graphite; those in the steel negative plate, with cadmium oxide and iron. The plates are covered with a solution of potassium hydroxide.

Edison Storage Battery Division



Nickel Cadmium Battery Corporation


Vent
Negative Terminal
Positive Terminal
All Negative Plates Connected Together
All Positive Plates Connected Together
Perforated Steel Pockets
Insulators Separating Plates
Steel Case

2. A toaster that is used on a 115-volt circuit allows a current of 1 ampere in it. What is its resistance?

3. Three dry cells are connected in series to operate a flashlight. If you had three bulbs marked 3.0 volts, 4.5 volts, and 6.0 volts respectively, which would you use in the flashlight?

4. An electric iron is marked 800 watts. How many watt hours would it use if operated for 2 hours.

5. If electricity costs 3 cents per kilowatt-hour, how much would it cost for the electricity used by the iron in problem 4, which is marked 800 watts and is operated for 2 hours?

6. A television set uses 300 watts of electricity. If it is used 4 hours each night for 30 days, and electricity costs 2 cents per kilowatt-hour, how much does the electricity used by the television set cost?

UNIT ACTIVITIES

APPLY YOUR KNOWLEDGE

1. One day a class of high-school students visited a large electric power plant. They noticed that both the armature and field of the large A.C. generator contained a number of electromagnets. There were no permanent magnets in either the armature or field. A few feet away was a small D.C. generator wired to the A.C. generator. The attendant told the students that the D.C. generator was called an "exciter." On your answer sheet, write the letter of the statement below which you believe would best explain the purpose of the D.C. "exciter."

   a. Uses the additional electricity available when only a few people in the city are using electric power.
   b. Turns the A.C. generator.
   c. Produces electricity for the field magnets of the A.C. generator so they in turn can produce a strong magnetic field through which the armature can pass.
   d. Produces the additional electricity needed when a large amount of electric power is being used by the people in the city.

2. Bill's mother needed some more outlets to which she could attach additional electrical appliances in her kitchen. She bought an extension cord to which she could attach three appliances. One day she attached a hot-plate that used 1,800 watts, a roaster that used 1,000 watts, and an iron that used 800 watts. Soon after they were all turned on, the cord became very hot and a fuse "blew out." On your answer sheet, write the letter of the statement which best explains why this happened.

   a. The cord was probably a cheap one and poorly insulated.
   b. The cord should have been covered with something other than rubber.
   c. The three appliances attached to the cord used too much current.

d. The heat from the three appliances was so great it melted the insulation on the cord.

e. The fuse was no good.

EXPLANATIONS ABOUT ELECTRICITY

1. With the aid of a drawing of a transformer, explain how it changes the voltage of electricity.

2. Tear an old dry cell apart and tell the purpose of each part.

3. By using a small electric motor, explain how it works.

4. Explain how objects, such as baby shoes, can be coated with metal to preserve them.

VISIT PLACES USING ELECTRICITY

1. Take a trip to an electric power plant to see how electricity is produced.

2. Examine a new house that is being wired for electricity, and note the precautions that are being taken to make the wiring safe.

3. Visit a substation to find out how it is operated.

LEARN ABOUT USING ELECTRICITY

1. Find the wattage of the electric appliances in your home and determine the cost of running each of them for an hour at the average rate that you pay for electricity.

2. Locate the wheel in your electric meter and observe the rate at which it turns when different appliances are being used. Compare its speed with the wattage rating on the appliances.

3. Make a list of all the electric appliances used in your home, and after the name of each appliance, tell what electric effect causes it to work.

READ ABOUT ELECTRICITY

Beeler, Nelson F., and Branley, Franklyn. *Electricity.* New York: Thomas Y. Crowell Company, 1949.

Includes directions for interesting demonstrations that you can perform with electricity.

Bendick, Jeanne. *Electronics for Young People.* New York: McGraw-Hill Book Company, Inc., 1947.

Although no one has ever seen an electron, you will think you have after reading this book with its interesting and amusing diagrams.

Caverly, Donald P. *Primer of Electronics and Radiant Energy.* New York: McGraw-Hill Book Company, Inc., 1952.

Easy to read digest of basic principles involved in electronics and radiant energy.

Eaton, Jeanette. *That Lively Man, Ben Franklin.* New York: William Morrow and Company, 1948.

Another book that will help you to understand how people can be scientists and how scientists can be people.

Epstein, Sam, and Epstein, Beryl. *First Book of Electricity.* New York: Franklin Watts, Inc., 1953.

Simple introduction to electricity, including home experiments for the beginner.

Electricity for Boys and Girls. New York: John F. Rider Publisher, Inc., 1954.

Clearly written answers to questions about electricity, electrons, atoms, batteries, and electrical terms, together with instructions for building a simple electric motor.

Richardson, Ralph A. *Electricity and Wheels.* Detroit: General Motors Corporation, 1939.

The first part of this book contains some interesting historical references

to man's increasing understanding of magnetism and electricity.

Shippen, Katherine B. *The Bright Design.* New York: The Viking Press, 1949.

The development of the electromagnetic theory is described through a series of brief stories about the people who were involved.

Skilling, Hugh H. *Exploring Electricity.* New York: The Ronald Press Company, 1949.

A fascinating story of the development of man's ideas about what electricity is, and how it works.

Yates, Raymond F. *The Boys' Book of Magnetism,* New York: Harper & Brothers, 1941.

Contains many suggestions of demonstrations you can do with magnets to help you learn more about magnetic forces. The excellent photos help make directions for the suggested demonstrations clear.

Mies van der Rohe, Museum of Modern Art

Houses, such as the one above, are designed and built to make greatest use of radiant solar energy in obtaining heat. This is one of the several ways in which heat is obtained.

unit 6 HEAT

As you remember from Unit 2, scientists believe that most of the matter of the universe, including that of which man and other living things are composed, is made of small particles called molecules. Furthermore, these molecules are thought to be in motion constantly. This constant molecular motion is now thought of as heat. Molecular motion, or heat, is the energy responsible for many life activities, and it can also be used to operate machinery.

Since almost everything on the earth contains molecules in motion, almost everything possesses heat energy. However, not all things possess heat to the same degree. Thus, both ice and boiling water possess heat energy, but the boiling water has it to a greater degree than the ice. Man can use for his practical operations only that heat energy given off when a substance changes from a condition in which it possesses a high degree of heat to one in which it possesses a low degree.

Man needs heat energy to run his machines, to cook his food, to keep him warm in winter, and for a variety of other purposes. Sometimes he can use radiant energy directly from the sun. At other times he must depend upon the energy that has been stored in fuels. At all times he should be interested in using heat as effectively as possible. Many of man's most important problems are concerned with producing, controlling, and using heat energy more effectively to meet his many needs. In this unit we shall learn how man is solving those problems.

U. S. Forest Service from Monkmeyer

In order to control a fire, it is necessary to do one of three things: cut off its supply of air, lower the temperature below the kindling point of the material that is burning, or remove the material.

chapter 12 OBTAINING AND MEASURING HEAT

HEAT energy is extremely important to us. It keeps the earth warm enough for living things to exist. It is the energy used in operating many of our machines. It also enables us to fashion many of the raw materials of the earth into the products we use every day.

Because heat is so important to man, scientists have studied it carefully for many years. They have learned several ways to obtain heat; they devised ways to measure and control it; and they discovered ways to use it economically. In this chapter you will learn how heat is produced, what scientists believe it is, and how it can be measured.

PROBLEM 1. How is heat obtained?

THE NATURE OF HEAT

If you have ever tried to describe heat, you probably found it very difficult. Heat is not something you can see, smell, or taste. For a long time it was believed to be a definite substance, and was called *caloric,* from a Latin word meaning "heat." It was thought that when a warm object was placed near a cold object, some "caloric" was transferred from the warm object into the cold object, thus warming it. But this idea about heat did not explain satisfactorily what happened when some materials became hot. For example, it was noted that when a small iron wire was bent back and forth rapidly, it became hot at the place where it was bent. Certainly no "caloric" was added to the wire, since there was no hot object next to it. How, then, could the wire become hotter at the bend?

The fact that the wire became hotter at the bend is now explained by assuming that heat is the movement of atoms or molecules making up any substance, such as the wire. Bending the wire increases the movement of molecules at the bend, thus making it hot.

How the sun warms the earth. Since most of the 93,000,000 miles between the earth and the sun is space, only radiant energy can reach the earth from the sun. You will recall that it is the rays of infrared radiant energy that produce most of the heating effects of the sun upon the earth (see page 120). Although these rays have traveled millions of miles through space when they reach the earth, they have not lost their power to increase the heat in the objects they strike. By increasing the movement of the molecules or atoms of the objects which absorb them, the rays produce sufficient heat to make life possible on the earth.

Increasing heat by burning or combustion. Our second important way of increasing heat is by burning fuels such as wood, coal, and oil (see Unit 2, pages 83-88). If you have ever tried to start a fire with wood or coal, you will recall that it is sometimes difficult to start the fuel burning. Before a fuel will burn with a flame, its heat must be increased until the substance reaches a temperature called the *kindling temperature.* Each substance has its own kindling temperature. Coal fires are generally started with paper and small pieces of wood as kindling. Paper is quickly raised to its kindling temperature with a burning match. The burning paper heats the wood to its kindling temperature. The burning wood in turn heats the coal to its kindling temperature, and the coal then burns with a flame.

Increasing heat with electricity. As you learned in Unit 4, an electric current is the movement of countless billions of electrons in a conductor. It is thought that the increase in heat observed in a conductor carrying electricity results from the increased motion of the electrons. Thus electricity is a source of heat.

You have also learned that electricity can be used to produce different types of radiant energy. This radiant energy in turn increases the heat of the materials that absorb it. Thus, electricity can indirectly increase heat.

Increasing heat by friction. Press the flat part of a fingernail tightly against this page, and rub it back and forth rapidly. Your finger is warmed because rubbing objects together increases the motion of their molecules. The increase in the motion of the molecules results from overcoming *friction*. Friction is the opposition offered by the two surfaces toward sliding over each other.

The early American Indians are said to have started their fires by rubbing two dry pieces of wood together until they became hot enough to kindle dry leaves or other material. Today Boy Scouts are taught to kindle fires in this manner so that they do not have to depend on matches.

Matches are lighted by friction. When you strike the match, the friction increases the heat of the chemicals in the match head enough for them to burst into flame. Matches are treated with chemicals so that they burn slowly with an even flame.

Friction causes automobile brakes to become hot while they are being used. The brakes are lined with a material that does not burn readily, but if they are not properly adjusted, the linings may be burned.

Increasing heat in other ways. Have you ever pumped air into a bicycle or automobile tire with a hand pump? You probably noticed that the rubber tube which carries the air into the tire becomes warm. As you force the piston down in the pump, the air molecules become crowded, or compressed, and they begin to move more rapidly. This increase in the speed of the molecules warms the tube. The increase in heat obtained is due to *compression*.

If you hammer a nail vigorously for a short time, you will find that it becomes hot. The pounding increases the movement of molecules where the nail is being hit. The increased heat produced by hammering or pounding is called heat from *percussion*.

Boy Scouts of America

Pulling the bow back and forth spins the stick of wood rapidly and produces heat by friction. Tinder with a low kindling temperature placed near the end of the stick soon burns, and in turn starts the camp fire.

Heat can also be increased by chemical reactions other than combustion. Mixing a solution of concentrated sulfuric acid and water, for instance, may cause a rapid increase in heat—so rapid, in fact, that special care must be taken to prevent accidents when these two substances are mixed. Remember always to pour the acid slowly into the water; never pour the water into the acid, because it may spatter. Some heating pads contain a chemical. A small amount of water added to this chemical starts an action increasing the heat.

SUMMARY

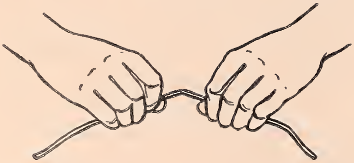
The heat of a substance is increased whenever the movement of its molecules or atoms is increased. The movement of the molecules of a substance may be increased by (1) radiant energy, (2) chemical reaction, (3) electric currents, (4) friction, (5) compression, and (6) percussion. Radiant energy, chemical reactions, and electric currents are the most commonly used means of obtaining the heat that we need.

TEST YOURSELF

In the proper place on your answer sheet write the letter of the ending which best completes each statement.

1. Of the following, the one with the lowest kindling temperature is (a) paper; (b) coal; (c) wood; (d) gasoline.
2. Increasing heat by rubbing two sticks together is an example of heat from (a) percussion; (b) friction; (c) chemical action; (d) static electricity.
3. Heat is thought to be (a) a substance that moves from a hot to a cold object; (b) the motion of the atoms or molecules of a substance; (c) a substance that moves from a cold to a hot object; (d) one of the chemical elements.
4. Increasing heat by burning a fuel is an example of heat from (a) percussion; (b) electricity; (c) chemical action; (d) compression.
5. The earth is warmed by the sun because it (a) receives heat from the sun; (b) obtains caloric from the sun; (c) absorbs radiant energy from the sun; (d) is attracted by the gravitational force of the sun.

OBSERVATION



What to observe. Two ways of increasing heat.

How to observe them. Bend a short piece of soft iron or copper wire rapidly back and forth. Feel the wire at the bend. Place a nail on a hard surface, such as a vise or anvil, and hammer it vigorously for a short time. Feel the nail where it has been hammered.

Interpretation of your observation. Write one sentence stating how heat was increased in the above situations.

PROBLEM 2. How is heat measured?

KINDS OF MEASUREMENTS USED IN SCIENCE

You will recall that most of the materials and forces we have considered so far were measured in some way. The characteristics of air and water, for example, were expressed in terms of certain measurement such as volume and weight. The sizes and positions of bodies of the universe too have been measured. Radiant energy is measured in terms of wave length, frequency, and amplitude. Before scientists were able to learn what they know today about electricity, they had to develop many measurements for electric currents. Likewise, in order to solve problems dealing with heat we must be able to measure heat and its effects on various things.

Methods of measuring temperature. As we learned in the last problem, heat is thought to be the movement of the molecules of a substance. The faster the molecules move, the hotter the substance becomes or the higher its temperature. Thus, increases in temperature could be determined by measuring increases in the speed of molecules. But molecules are so small that such measurements would be too complicated for practical purposes.

Scientists therefore approached the problem of measuring temperature by the *if—then* method described on pages 72-73. First they assumed that when the temperature of a substance increases, the average movement of its molecules increases (see page 29). The increased movement of the molecules of a substance causes them to be spread farther apart, thus increasing the amount of space they occupy, or increasing the volume. By measuring the increase in the volume of a substance they could, therefore, obtain an indirect measurement of its increase in temperature. Temperature measurements are made with thermometers. (See page 233.)

Construction of a mercury thermometer. The picture on page 233 shows one kind of thermometer. The bulb at the base and the stem are made of glass. The bulb is filled with mercury. The stem has thick walls through which a tiny hole runs from the bulb to the top, where the stem is sealed.

When the bulb of the thermometer is placed in a substance whose temperature you want to find, the mercury inside the bulb soon becomes the same temperature as the substance around it. If the mercury is warmed by the substance, the average speed of its atoms is increased, and they occupy more space; that is, the mercury *expands.* Since the tiny hole in the stem is the only place into which it can move, it rises in the stem. If, on the other hand, the mercury is cooled, its atoms move more slowly. They take up less space, and the mercury is said to *contract*. The mercury then falls in the stem because more of it can get into the bulb.

The rise or fall of the mercury in the stem of a thermometer indicates only that the temperature has increased or decreased. The exact amount of change is shown by lines on the stem. The lines are equally spaced and the distance between them is called a *degree of temperature.*

Fahrenheit and centigrade thermometers. The degree lines on a thermometer are determined in the following manner. First, the thermometer is placed in water which contains melting ice. A mark on the stem showing the position of the mercury indicates the melting point of ice, or the freezing point of water. Next, the thermometer is placed in steam from water that is boiling at sea level. The mercury rises to a new position in the stem. This point is also marked on the stem to indicate the boiling point of water. The distance between these two marks is divided into degrees indicated by equally spaced lines.

For the Fahrenheit thermometer, the mark at the boiling point is labeled 212°, while that at the melting point of ice is labeled 32°. The space between these points is divided into 180 equal parts, each space representing one degree. The Fahrenheit thermometer is commonly used for everyday purposes in the United States.

The centigrade thermometer shows the boiling point of water as 100° and the melting point of ice as 0°. The distance between these two points is divided into 100°. The centigrade thermometer is used for all purposes in European countries, except England, and in science laboratories throughout the world.

It is often necessary in the laboratory to change the temperature reading on a Fahrenheit thermometer to the corresponding centigrade reading. This is done very simply by subtracting 32° from the Fahrenheit reading and dividing the result by 1.8. For example, if your Fahrenheit thermometer reads 68°, the centigrade reading is 20°. To change from a centigrade reading to a Fahrenheit reading, multiply the centigrade reading by 1.8 and then add 32°. You can readily see that 10° centigrade is the same as 50° Fahrenheit.

Difference between temperature and total heat of a substance. On a hot summer day you may find the temperature to be as high as 90° Fahrenheit. What does 90° Fahrenheit mean? Is the thermometer registering the total amount of heat in the air? No, it is not. Instead, it is registering merely the hotness or coldness of the air as compared with melting ice and boiling water. This is different from the total amount of heat in the air.

Suppose one thermometer were placed in a cup of water and another thermometer were placed in a gallon pail of water, and it was found that the temperatures were the same. Now suppose both the cup and the pail were placed over the same size gas flames. Which would be the first to show an increase of 10° in temperature? The water in the cup would. Which would require more heat to increase the temperature 10°? The water that is in the pail, of course. Yet after the temperature of the water in each container has been raised 10° the temperature of the water in the two vessels will again be equal. Evidently a thermometer does not measure the total amount of heat the water gains.

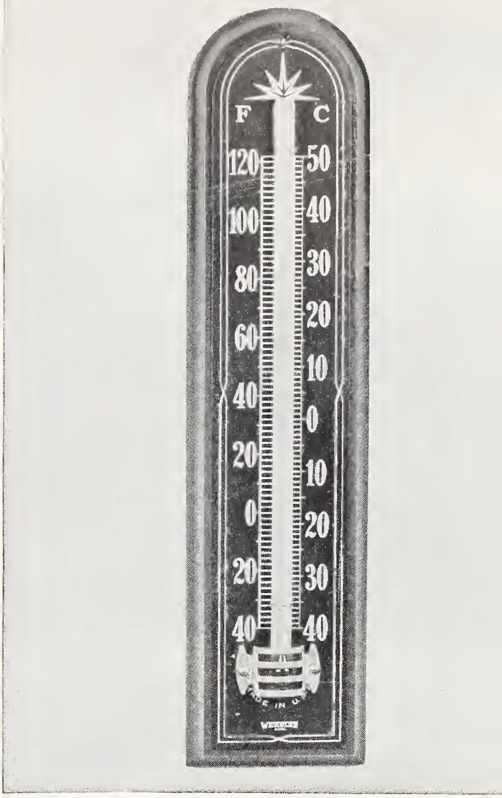
To explain what a thermometer does measure, let us assume that when the temperatures were equal, the average speed of molecules of water in the cup was the same as that of the molecules of water in the gallon pail. When the heat of the water in the cup and the water in the pail was increased, the average speed of the molecules of water was increased. But since there were more molecules in the pail than in the cup, it took the gas flame longer to increase the average speed of the molecules in the pail by a certain amount than to increase the average speed of the molecules in the cup by the same amount. The thermometer reading, therefore, depends upon the average speed of the molecules in a substance. Thus, when a thermometer registers 90° Fahrenheit, it is really indirectly comparing the average speed of the molecules of air to that of the standard (the melting point of ice and the boiling point of water) (see page 29). Its reading gives no indication of the total number of air molecules that are moving. The thermometer, therefore, does not measure the total amount of heat of the air.

Measuring heating effect of fuels and food. Fuels and foods are often selected on the basis of their heating effect when oxidized (see page 31).

Two units for measuring the heating effect of foods and fuels are in common use in the United States. They are the *British thermal unit* and the *large Calorie*. A third unit, the *small calorie,* is used in science laboratories throughout the world.

The amount of heat required to raise the temperature of one pound of water 1°F is called a British thermal unit, often abbreviated as Btu. The heat value, or heating effect, of most fuels is given in Btu's. Fuel oil used in home furnaces, for instance, has a heat value ranging between about 18,000 and 20,000 Btu's per pound.

A large Calorie is the amount of heat required to raise the temperature of one kilogram of water 1°C. Note that it is spelled with a capital letter. A kilogram is a metric unit of measurement equal to about 2.2 pounds. The small calorie is the amount of heat that is required to raise the temperature of one gram of water 1°C. Since a gram is one-thousandth of a kilogram, the small calorie, spelled with a small letter, is one-thousandth of the large Calorie. The heat value of foods is expressed in Calories.



Weksler Thermometer Corporation

A thermometer with both the Fahrenheit and centigrade scales for measuring temperature. Note that 0°, freezing point on the centigrade scale at the right, is the same as 32° on the Fahrenheit scale at the left.

Taylor Instrument Company

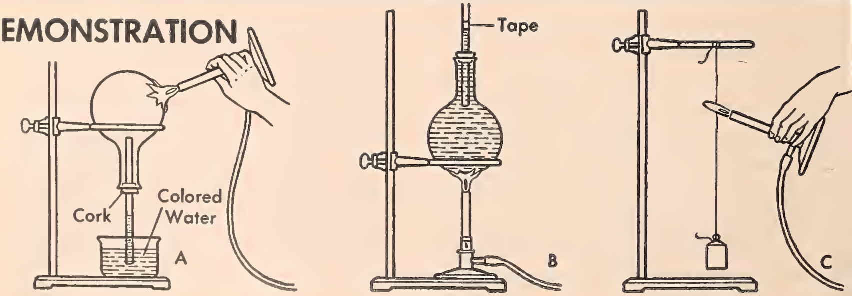
Thermometers aid in the proper cooking of different kinds of food. The thermometers are being used to measure temperatures of a candy mixture, fat, the oven, and the roast.

The actual measuring of the heating effect, or *caloric value,* of a substance such as a fuel or a food is a difficult process. The apparatus used for this purpose is called a *calorimeter*. It consists of a large container constructed to prevent loss of heat from its interior. Inside this container is a smaller one which holds one liter (1,000 grams) of water. A third, still smaller container is suspended in the water. Suppose one gram of the material to be tested is burned inside the smallest container. The heat produced as the material burns raises the temperature of the surrounding water. The increase in temperature is measured with a thermometer. The caloric value of the material burned is determined from the increase in the temperature of the liter of water. For example, if the temperature of the liter of water increased 1°, the caloric value of the material burned was one Calorie per gram.

SUMMARY

The temperature of a substance is an indirect comparison of the average speed of its molecules or atoms with that of a standard, water. Temperatures are measured with thermometers. The total amount of heat which a substance contains depends both upon the temperature of the substance and the total number of molecules it contains. Through oxidation foods and fuels produce a heating effect. This effect can be measured in definite units with a calorimeter.

DEMONSTRATION



Generalization to be demonstrated. Many substances expand when heated and contract when cooled.

What you need. Flask (Florence type); single-hole rubber stopper to fit flask; glass tubing 8 inches long to fit hole in stopper; colored water; 2 feet of iron wire; ringstand with burette clamp; tape; small weight; Bunsen burner, beaker or pint jar.

What to do. 1. Set up the apparatus as in A above. (**Caution.** Wet the glass tubing before inserting it in the cork. Prevent the tubing from accidentally cutting your hand by holding it inside several folds of cloth.) Gently warm the flask, and watch the end of the glass tubing. Now cool the flask by pouring some cold water over it.

2. Fill the flask with colored water, as in B, so the water level is about half way up the tube when the cork is inserted. Mark the level with tape. Heat the flask gently, and watch the water level in the tube. Cool the flask and watch the water level.

3. Support the weight with the iron wire, as in C, so that it just clears the base. Heat the wire by moving the Bunsen burner flame up and down the wire, and observe the position of the weight with respect to the base. Allow the wire to cool, and again note the position of the weight.

What to observe. 1. Do bubbles of air escape from the end of the tubing as the inverted flask is heated? Where does some of the colored water go as the inverted flask is cooled?

2. How does the water level inside the tube change as the flask filled with water is heated and then cooled?

3. How does the position of the weight with respect to the table top change as the wire is heated and then cooled?

What does it mean? 1. How does heating and cooling affect air, water, and iron wire?

2. What assumption would you have to accept to use the observations you have made of air, water, and iron wire as proof of the generalization stated at the beginning of this demonstration?

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Temperature is an indirect measure of the (a) number of molecules in a substance; (b) size of the molecules of a substance; (c) speed at which the molecules of a substance are moving; (d) weight of the molecules of a substance.
2. When mercury is heated it (a) expands; (b) contracts; (c) does not change its volume; (d) becomes a solid.
3. If water at 100° C were measured

with a Fahrenheit thermometer, it would have a Fahrenheit temperature of (a) 0°; (b) 32°; (c) 212°; (d) 132°.

4. The heating value of food is most often measured in (a) Btu's; (b) calories; (c) Calories; (d) degrees.

5. A kilogram is equal to (a) 2.2 pounds; (b) 500 grams; (c) 1000 pounds; (d) 2000 pounds.

CHAPTER ACTIVITIES

RECOGNIZE ASSUMPTIONS

Bill read in his science book that fuels give off different amounts of heat when they are burned. To gather some evidence to test this statement, he obtained three equal-sized beakers, put the same amount of water in each beaker, and placed each of them on a ringstand. He placed a thermometer in each beaker. Two inches below each beaker he placed a small container. He poured a sample of alcohol into the first container, gasoline into the second, and kerosene into the third. He lighted each fuel and, after it had burned, he measured the temperature of the water in the beaker above it. He found the temperatures of the water in the three beakers were not the same after the samples of fuel were burned. He concluded that his results proved the statement he had read in his book. On your answer sheet, write the number of each of the following statements which is an assumption that, if the tests were carried out exactly as described above, you would have to accept before you could agree with Bill's conclusion.

1. Ether, alcohol, and gasoline are fuels.

2. The temperature of the water in the beakers was the same before the fuel was burned.

3. Equal amounts of each of the fuels were burned under each beaker.

4. Each fuel sample was two inches below the beaker.

5. The increase in temperature of the water in each beaker was caused only by the heat from the fuel under the beaker.

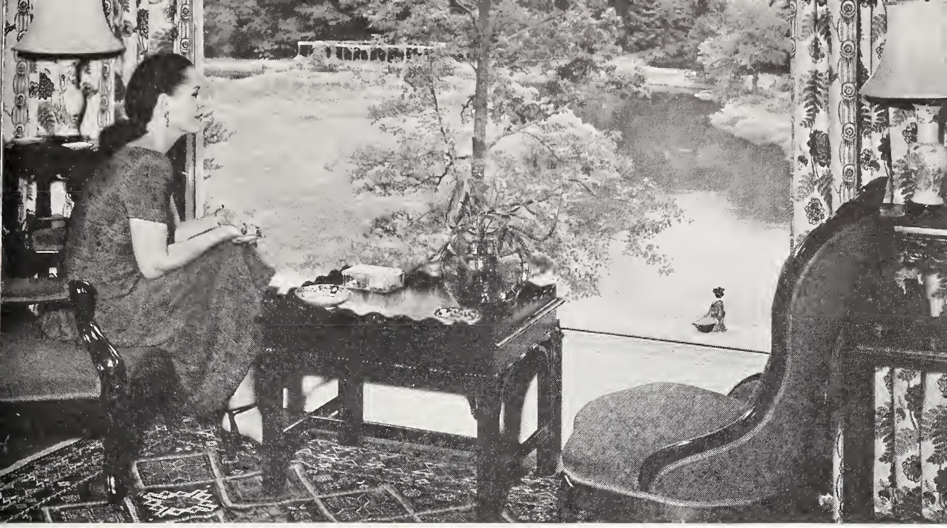
6. A thermometer can be used to measure temperature.

7. All of the heat produced by each fuel was used to increase the water temperature.

8. Equal amounts of water were put into beakers of the same size.

9. Similar differences would be found if all fuels had been tested.

10. The three beakers used were of the same material.



Pittsburgh Plate Glass Company

A large picture window provides a beautiful view all year round. Made of two plates of glass separated by an air space, it also keeps heat in the house in winter.

chapter 13 CONTROLLING HEAT FOR COMFORT

WE seldom realize what a limited range of temperature we require in order to work efficiently and be comfortable. We do our best work most comfortably in a temperature range of from 65° to 75°F. When the temperature is above 80°F we are uncomfortably warm, and we often close our schools, factories, and places of business when the temperature climbs higher than 90°F. On the other hand, finding temperatures below 60°F uncomfortably cold, we protect ourselves against them by wearing heavier clothing and heating the buildings in which we live and work. There are a number of ways to control heat to provide the temperatures at which we work and live most comfortably.

PROBLEM 1. How is the heat of our bodies controlled?

BODY HEAT AND TEMPERATURE

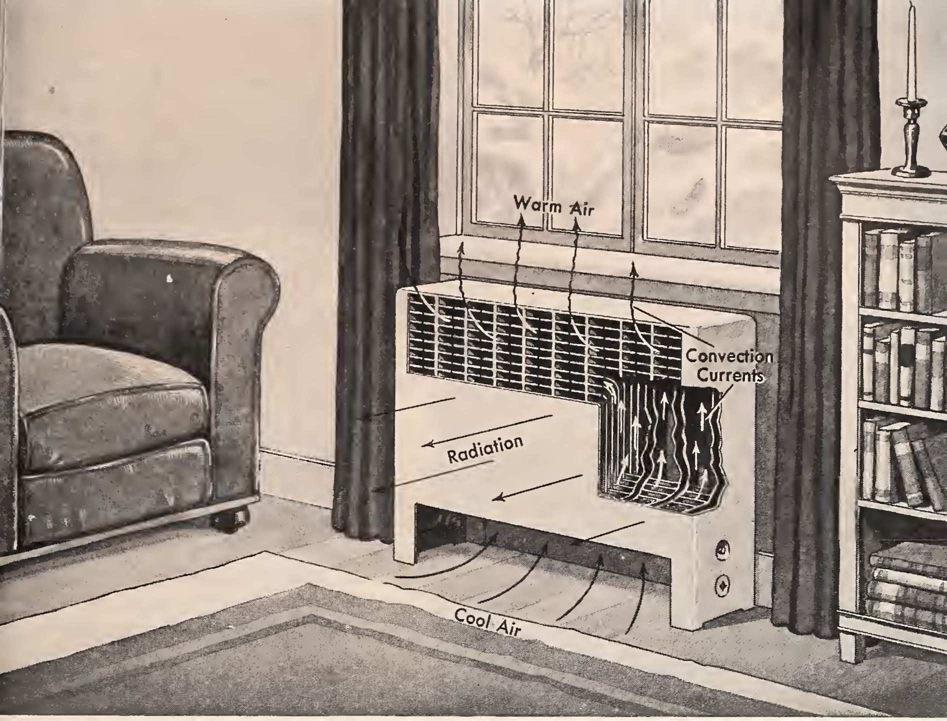
It has been learned that the temperature of the healthy human body is 98.6° F. In order to function properly, the body must maintain this temperature. The heat produced in the body is the result of the chemical changes necessary to carry on body activities. The ordinary activities of the body generally produce more heat than is necessary to keep it at 98.6°, and vigorous physical activity increases the amount of heat produced. During warm weather it is sometimes difficult for the body to give off extra heat. At such times a person becomes uncomfortably warm and must assist the body in giving off heat. During cold weather, when the body loses heat much faster than in warm weather, it becomes necessary to prevent the body from losing too much heat.

Probably the most practical means of controlling body heat is to regulate its losses from the body. The body loses heat to other objects by *conduction, convection, radiation,* and through *evaporation.* An understanding of the four processes should make it possible for us to regulate heat losses more effectively.

Conduction. If you stir a cup of hot cocoa with a sterling silver spoon, you will find that the handle of the spoon soon becomes hot. Evidently heat has moved from the cocoa to the spoon handle through the spoon itself. Such movement of heat through a substance is known as conduction. A substance through which heat will move in this way is known as a conductor of heat.

Heat moving by conduction can be explained by an example. When the end of an iron rod is placed in a fire, the heat of the fire causes the movement of the molecules in that end of the rod to increase. These molecules then cause the molecules next to them to move more rapidly. They in turn increase the movement of the molecules next to them, and so on, until the movement of the molecules at the other end of the rod has been increased, thus making this end hot. A substance like iron, in which the molecules readily transfer their motion from one to another, is a good conductor of heat. Most metals are good conductors of heat (as well as of electricity), silver being the best conductor, with copper a close second. A substance like asbestos, in which the molecules cannot transfer their motion easily from one to another, is a heat insulator.

Convection. You have probably often stood near a hot stove or radiator and felt a current of warm air rising above it. This current of air is known as a convection current. It is created by a combination of molecular motion and gravity. As the air over a radiator or stove becomes hot, it expands. When it does so, there are fewer molecules than before in a given space, but they are moving faster. The warm air therefore weighs less than the unheated air in other parts of the room. Because the warm air is lighter, the heavier cold air moves in under it, and forces it upward. This cold air in turn is heated and forced upward by other cold air, thus creating a convection current. Because air moves freely from place to place, all the air in a room can easily be heated by convection currents. Convection



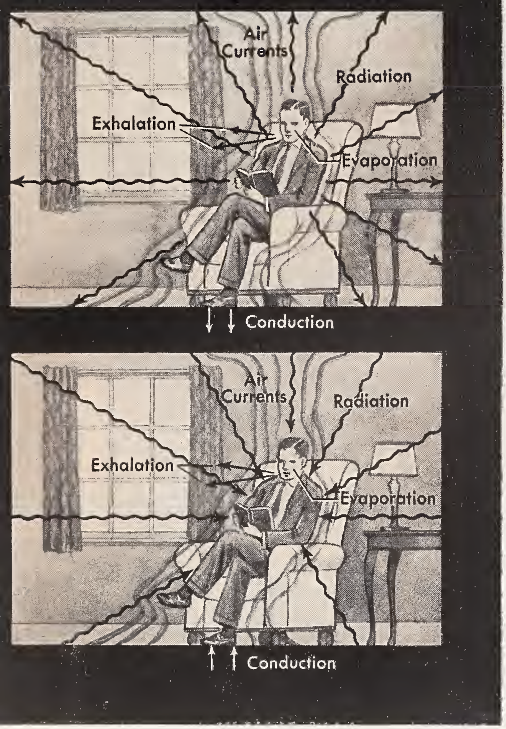
Heat in a steam or hot-water radiator is transferred to the air in a room by convection currents and by radiation. The way convection currents pass through a radiator is shown in the cutaway section of this radiator.

currents cause the drafts in fireplaces and furnace chimneys, the circulation of air in some kinds of home heating systems, and much of our weather. Convection currents occur only in gases and liquids whose molecules are free to move.

Radiation. We have learned that the heat we obtain from the sun is *not* transferred directly from the sun to the earth as heat. Because of its hotness, the sun gives off high-frequency infrared rays of radiant energy. When these rays strike objects on the earth, the movement of the molecules making up those objects is increased, causing the objects to become heated. These heated objects in turn give off low-frequency infrared rays. The process of losing heat by giving off radiant energy is known as radiation.

Experiments have shown that black rough objects absorb radiant energy, thus being heated by it. Polished, silvery or white objects, on the other hand, reflect most of the radiant energy and do not become very hot.

Evaporation. As you will recall, when the speed of water molecules gets high enough, they escape from the liquid to become a gas (see page 30). Since it is the high speed molecules that tend to escape, their escape lowers the average speed of the water molecules. Since the average speed is lowered, the temperature drops. Thus



In an unheated room (top), a person loses most of his body heat by radiation to objects in the room colder than the body. In a room that is radiant heated (bottom), a person's body obtains heat by radiation from warm surfaces.

evaporation is a cooling process. When evaporation is rapid, the body cools quickly; when evaporation is slow, it is cooled scarcely at all. On damp days when the air has a large percentage of water vapor, perspiration evaporates slowly. Then the body is cooled very slowly, and we feel uncomfortably warm. When the temperature is high but the air contains only a small amount of water vapor, perspiration evaporates fairly rapidly and we feel comfortable. A movement of air, such as a breeze, increases the rate of evaporation of perspiration, because it brings air containing less water vapor in contact with the body.

CLOTHING TO CONTROL HEAT

Clothing for hot weather. Clothing to be worn in hot weather should be light in weight and should be woven so that air can pass through it freely to remove the heat from the body by convection and evaporation. Probably the most important characteristic of summer clothing is its ability to absorb perspiration from the body and spread it over a large area, so that it can evaporate as rapidly as possible. Linen clothing is especially desirable for summer wear, for it absorbs perspiration readily and releases it into the air easily. Cotton, silk, and rayon materials are also widely used for summer clothing.

Light-colored clothing is more satisfactory than dark-colored clothing for warm-weather wear, since it reflects more radiant energy than dark-colored clothing, and therefore is warmed less. For this reason, light-colored clothing is usually worn in tropical regions.

Clothing for cold weather. In cold weather we try to keep comfortable by keeping heat from decreasing in our bodies. We therefore select clothing that will permit as little heat as possible to be removed. Woolen clothing is especially good for preventing loss of heat by conduction and convection. Wool fibers are poor conductors of heat. Furthermore, because the fibers are curled and elastic, the cloth into which they are woven contains a great many tiny pockets of air. These air pockets, called *dead air spaces,* are so small that convection currents are not easily started. Since air is a poor conductor of heat, the dead air spaces prevent loss of heat by conduction. They also reduce heat loss from the body by retarding evaporation. Two loosely fitted garments are warmer than a single heavy garment, for air is trapped between them, thus providing additional dead air space. For this reason, coats made in layers are warmer than a single thick coat. To reduce the amount of heat loss from the body by wind, the outer layers of the coat should be made of tightly woven material to prevent the wind from blowing through the coat and removing heat from the body by evaporation and convection.

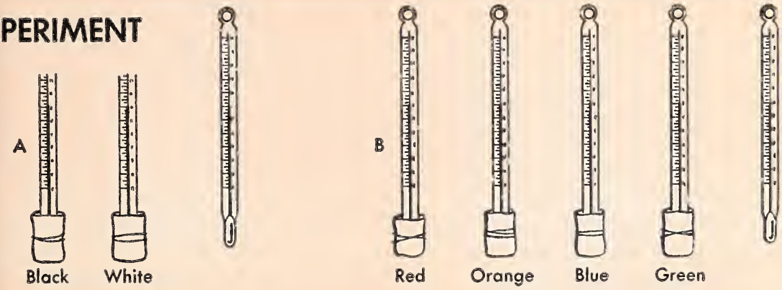
Glass can be drawn into tiny fibers smaller than a hair and made into light, effective insulating material called *glass wool*. Clothing containing this material as an interlining is warm and light.

Although about one half of the heat lost by the body is lost through radiation, very little has been done in constructing clothing to reduce this loss. Materials which are good insulators against heat loss by conduction and convection are usually ineffective in preventing heat losses by radiation. The radiant energy goes right through the material or is partly used in heating it. But it has been found that a single thickness of *aluminum foil* (very thin sheet of aluminum), when used as an interlining in a jacket, is very effective in reducing heat losses from the body by radiation. The foil also helps make the jacket wind-proof.

SUMMARY

Heat losses from the body must be regulated to maintain a body temperature most suitable for its normal functioning. Heat is lost from the body by conduction, convection, radiation, and evaporation. During the summer, clothing should be selected that will increase the loss of body heat by these methods. During the winter, clothing should be selected to prevent loss of body heat.

XPERIMENT



Generalization to be tested. 1. A dark-colored substance is heated more by radiant energy than a light colored substance is.

2. The warm colors (red-orange) absorb more radiant energy than the cool colors (blue-green).

What you need. Five thermometers (if five are not available, experiment can be done with one thermometer by doing one measurement at a time); pieces of black, white, red, orange, blue, and green cloth; tape.

What to do. 1. Place three thermometers, prepared as in A above, alongside each other but shaded from the sun's rays. Watch the temperature. After there is no longer a temperature change, record the temperature of each. Now place them in direct sunlight. Record the temperature of each thermometer at one minute intervals up to 10 minutes.

2. Repeat part 1, using colored cloth rather than black and white.

Your answer. 1. Write one sentence comparing the effect of radiant energy on black cloth with its effect on white cloth. Does your statement tend to prove or disprove the generalization being tested?

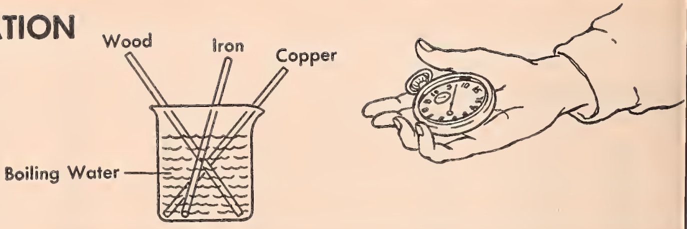
2. List the colors in order of the effect of radiant energy on them. Add black and white to the list. Do the words "warm" and "cool" describe the relative heating of the colors by radiant energy?

Some assumptions in this experiment. 1. Any temperature changes were the result of the absorption of radiant energy by the cloth.

2. The heating effect of radiant energy on all colored substances is the same as it was for the cloth used in this experiment.

3. The temperature differences resulted from color differences rather than differences in kind of cloth used.

DEMONSTRATION



Generalization to be demonstrated. Materials vary greatly in their ability to conduct heat.

What you need. One rod each of wood, copper, and iron, about ⅛ inch in diameter and 6 inches long; a beaker; a Bunsen burner; some water; a watch.

What to do. Stand three rods in hot water so that the same amount of each rod is beneath the water. Place one finger against the exposed end of each rod.

What to observe. How long is it before you detect a change in the temperature of each rod?

What does it mean? How does the difference in time noted above show that the three materials vary in their ability to conduct heat?

Some basic assumptions. 1. The rise in temperature at the end of each rod was caused by heat conducted by the rod.

2. Each of your three fingers is equally sensitive to heat.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The word which does *not* refer to a method of heat transfer is (a) conduction; (b) convection; (c) radiation; (d) resistance.
2. The primary way in which perspiration helps cool the body is by (a) conduction; (b) convection; (c) evaporation; (d) radiation.
3. Heat is required to change a liquid to a gas because (a) the molecules must move faster as a gas; (b) the molecules move more slowly as a gas; (c) the gas molecules are smaller; (d) the liquid must always be boiled.
4. Radiant energy heats an object most effectively when the object is (a) a silvery color; (b) smooth and black; (c) rough and black; (d) smooth and silvery.
5. Clothing helps keep the body warm in winter by (a) keeping the cold out; (b) preventing heat loss from the body; (c) aiding heat loss from the body; (d) increasing the conduction of heat from the air to the body.

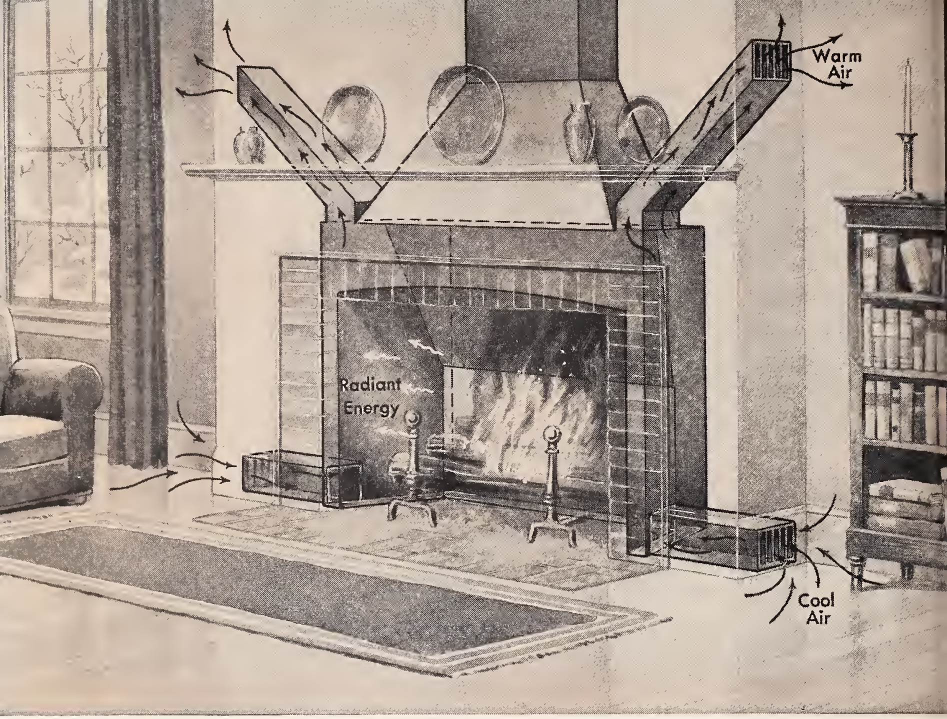
PROBLEM 2. How can heat in buildings be controlled?

EARLY HEATING SYSTEMS

Throughout the centuries, man has attempted to improve the heating systems used in his buildings. Yet all heating systems, from the most primitive to the most modern type, heat buildings by conduction, convection, and radiation. Heating systems differ primarily in the extent to which they depend upon convection and radiation for warming the rooms.

Open fires and fireplaces. Probably the first means of indoor heating used by man was the open fire. The radiant energy given off by the fire and the convection currents set up in the air heated the room. The smoke escaped through an opening in the roof.

Placing the fire in a fireplace with a chimney through which the smoke could pass provided less heat than the open fire. Though the smoke was satisfactorily removed from the room, the heating effects of convection currents were almost completely lost and only the radiant energy heated the room. Also, cold air from all parts of the room entered the fireplace along the floor so that there were always drafts. Heating was improved somewhat when the fireplace was built larger with a framework of stones which when warm gave off radiant energy.



This fireplace is constructed with a metal shell around it through which air can be circulated by convection currents. Both convection air currents and radiant energy are used to heat the room. In rooms heated by fireplaces without the shell, most of the heat must be obtained from radiant energy.

It is possible to construct a fireplace that will aid materially in heating a room. If the fireplace is lined with sheet metal, with a space between the metal and the walls, the air in the space becomes heated and enters the room through openings in the wall. In some cases, electric fans can be installed to provide more rapid circulation of the air than can be obtained by convection currents.

Heating stoves. The heating stove is a great improvement over the fireplace. Placed near the center of a room, it sends radiant energy to all parts of the room and readily produces convection currents. Sometimes the stove is surrounded by a metal jacket so arranged that the air enters it at the bottom, becomes warmed, and leaves at the top. Such heaters are called *circulating heaters* or *circulators*. They heat the room mainly by producing convection currents, little heat being transferred by radiation. Both plain heating stoves and circulators are widely used.

CENTRAL HEATING SYSTEMS

Central heating systems can be classified into three types: (1) hot-air, (2) steam, (3) hot-water. An understanding of the advantages of each type of heating system will enable you to obtain the greatest possible comfort from the system used in your home.

Hot-air heating systems. The heating unit of the hot-air heating system is a *furnace,* usually located in the basement of the house. The hot-air furnace is simply a large stove with a jacket built around it. The air inside the jacket is warmed and then carried by one or more pipes throughout the house.

Some hot-air furnaces depend upon convection currents to heat the house. One such furnace is called a *pipeless furnace*. The jacket of a pipeless furnace is built in two parts, one inside the other, and opens into one room through the floor. The opening is covered with a metal framework through which air can pass. The hot air enters the room through the central portion of the jacket, and the cold air flows down to the furnace through the outer portion of it. Hot air is thus transferred from the furnace to the house by convection currents.

A pipeless furnace is inexpensive to install and is usually inexpensive to operate. It will heat a small home, especially if air can circulate from room to room. However, the floors are often cold because all the cold air must travel along them to reach the furnace. The uneven heating also causes drafts in the house.

In a *pipe furnace,* a cold-air and a hot-air pipe from the furnace enter each room in the house. A pipe furnace costs more to install than a pipeless one, but it provides better circulation of the air. Besides, the floors are usually warmer, and there are fewer drafts because the cold air can return to the furnace through pipes from each room. Some hot-air systems provide for obtaining fresh, cold air from outside the house. These are more expensive to operate.

Hot-air heating systems in which the air is circulated through the house by a large electric fan installed in the furnace are known as *forced hot-air* systems. Hot- and cold-air pipes enter each room. Although these systems are rather expensive to install, they provide for more rapid circulation of the air than can be obtained from convection currents alone. Air-conditioning units can be installed in this type of heating system (see pages 33-35).

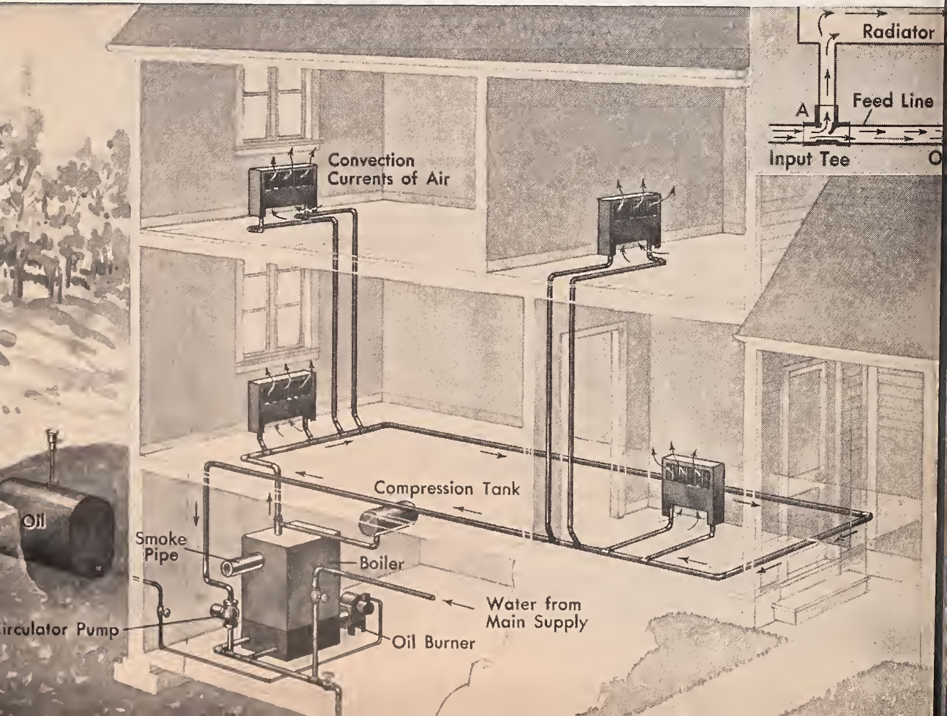
Steam-heating systems. In the steam-heating system, the furnace is constructed so that water is changed to steam in a boiler. The steam is then piped to *radiators* in each room. The drawing on page 239 shows how air around the radiator is heated. Steam-heating systems are especially effective in heating large buildings because the pressure of the steam forces it rapidly to distant rooms.

Why is steam a good heat carrier? If you place a thermometer in a pan of water that is being heated, you will find that the temperature rises steadily until the water reaches the boiling point. Once the water boils, the temperature no longer rises, although it is necessary to continue heating the water to keep it boiling. Continued heating does not increase the temperature of boiling water. Where, then, does the added heat go? It is used in changing water to steam. Although the temperature of the steam is the same as that of the boiling water, the steam contains more heat than the boiling water, because about 540 calories of heat are needed to change one gram of water to one gram of steam with no change of temperature. Therefore, when the movement of the molecules in one gram of steam decreases so that the steam condenses to water, 540 calories of heat are released with no change in temperature. For example, when 10 grams of steam at 100°C in a steam-heating system condense, they release the 5,400 calories of heat that were used to vaporize 10 grams of water.

Hot-water heating systems. In a hot-water heating system, hot water is used in the radiators instead of steam. The water is generally heated to about 180° F. Hot-water radiators are therefore not as hot as steam radiators, and more radiator surface is required to heat a room. Hot-water heating systems are widely used in homes because they produce an even heat.

Some hot-water heating systems depend upon convection currents to circulate the water through the radiators. In such a system, the radiators must be higher than the furnace in which the water is heated. These systems can therefore be used only when the furnace can be placed in a basement. Since convection currents alone circulate water slowly, this method generally takes a long time to heat a cold room. In some hot-water heating systems, centrifugal pumps rather than convection currents are used to circulate the water through the radiators. These pumps force the hot water

A hot-water heating system in which water is circulated through the radiators by a pump. A thermostat in one room turns the circulating pump on when the temperature of the room drops, and turns it off when the room becomes warm. A thermostat attached to the boiler turns on the oil burner when the water temperature drops. At A the flowing hot water strikes the scoop built into the Tee, creating a pressure that forces water to the radiator. At B water flowing by the scoop is speeded up due to the constriction. This decreases the pressure so that water in the pipe from B to C, acting like a siphon, circulates faster through the radiator.



through the radiators faster and therefore make the heating system more effective. When pumps are used, the radiators need not be higher than the furnace. Such a system can therefore be used in houses without basements.

Radiant-energy heating systems. Radiant energy can keep our bodies warm even when the temperature of the surrounding air is quite low. Because of its many sunny days, Sun Valley, Idaho, is a famous winter resort. The radiant energy is sufficient to make people feel comfortable in light clothing even though there may be snow on the ground. Radiant energy is also used to heat houses.

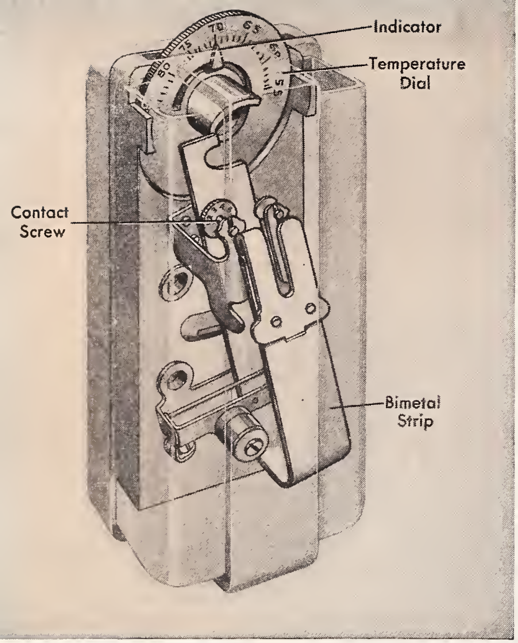
Radiant-energy heating systems are merely hot-water systems with pumps to circulate the water through coils of pipe rather than through radiators. However, the temperature of the water is generally only about 90°F. The coils can be placed in the floor, walls, or ceiling of a building. When these parts of the building are warmed, their entire surfaces give off radiant energy, which warms everything in the room, although the air is heated least. Since the walls and furniture are warm, radiant energy is not lost from your body as it is when the wall temperatures are lower. You therefore feel comfortable even though the thermometer may register an air temperature of only 65°F. Radiant-energy heating systems require no radiators to take up space in the room; there are no drafts from convection air currents, and the house is evenly heated throughout.

Controlling heat loss in buildings. If on a cold day you should place one hand on a windowpane and the other on the wall next to it, both surfaces would feel cool, but the windowpane would feel the cooler. The glass windowpane is a better conductor of heat than the wall. Both windowpanes and walls allow large amounts of heat to escape from houses unless steps are taken to reduce the heat loss. Then, too, there are often small cracks around the doors and windows that allow the warm air to escape from the house. Reducing such heat loss in as many ways as possible often results in a saving of as much as one third of the fuel burned each season.

Loss of heat through the ceiling and walls of a house can be reduced by placing insulation material in the space between the plaster and outer wall. Good insulation material is made from substances that are poor heat conductors; it is processed so that it is filled with dead air spaces. Plant fibers treated so that they will not burn easily, asbestos, glass wool, and minerals are often used as insulation materials. These materials prevent heat loss by conduction and convection. Loss of heat by radiation can be reduced by placing paper coated with shiny aluminum foil between the walls.

Storm windows will reduce the loss of heat through the windows. A tight-fitting storm window forms a dead-air space between the two glass panes. The dead air space is a good insulator. For best results, care must be taken that the storm sash fits tightly. On page 237 is shown a way to reduce heat loss by double glass panes.

Strips of felt or metal, known as *weather strips,* placed around doors and windows will prevent some cold air from entering the house. They are especially effective in reducing loss of heat if a house is located where there is considerable wind in the winter.



A diagram of a thermostat. When the bimetal strip is warmed, it bends outward, opening the contact and closing off the heat. As the strip cools, it bends inward, closing the contact and turning on the heat.

Thermostats help keep the house temperature even. A stove or furnace that is fired by hand usually produces uneven temperatures. At first the temperature is too high, then it is too low. More even temperatures can be obtained by controlling the firing of the furnace with an instrument called the *thermostat*.

The principal parts of a thermostat used in heating systems are shown above. The thermostat can be set so that the temperature in a house may not vary more than four or five degrees Fahrenheit during twenty-four hours. It is generally placed inside the house, although double thermostats, one outside and one inside the house, provide better control of temperature than a single indoor thermostat.

FUELS FOR HEATING

Any substance which may be burned to supply heat is considered a fuel. Fuels are generally divided into three class—solids, liquids, and gases. The solid fuels include wood, charcoal, coal, and coke. Oil is a liquid fuel commonly used in heating our homes. Both natural gas and manufactured gases are used as fuels. All these fuels contain compounds of carbon and hydrogen. The heating value of a fuel depends upon the proportions of hydrogen and carbon in the fuel that will combine with oxygen during combustion.

Wood and charcoal. In sections of the country where wood is plentiful, large quantities of it are used for fuel. Wood is also a popular fuel for use in fireplaces. The heating value of wood is low compared with that of other fuels. It is therefore not economical when it must be transported great distances. Wood-burning stoves and furnaces must have large *fireboxes* because large quantities of wood must be burned at one time in order to produce sufficient heat to warm a building on very cold days.

Charcoal is made by heating wood in large oven-like structures called *kilns*. Because air is excluded from the kilns, the carbon is not burned, but many of the other elements in the wood are driven off as gases. Thus charcoal, being mostly carbon, has three or four times the heating value of wood. It burns with no smoke, leaving little ash. It is popularly used for cooking purposes on picnics. It is also a source of heat in certain kinds of metal work. In the United States charcoal is not commonly used for heating buildings. But in countries such as Japan, where other types of fuel are scarce, it is used to heat homes. It is burned in open containers in several rooms of the house, but one must be close to the burner to be warmed.

Coal and coke. Coal is one of our most commonly used fuels for heating buildings. As we have previously learned, there are two principal types of coal—hard coal, or anthracite, and soft coal, or bituminous. Anthracite burns with less smoke and leaves fewer ashes than bituminous. When it has to be shipped long distances, coal is an expensive fuel. It is also dirty to handle and requires large storage space.

Coke is produced by heating bituminous coal in the absence of air in somewhat the same manner as charcoal is produced from wood. Some of the gases given off are used as gaseous fuel.

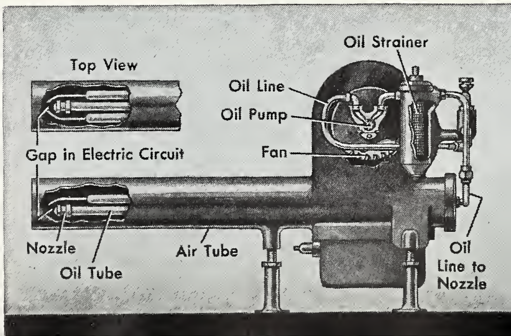
In a coal-burning furnace, the fuel is supported on an iron frame called a *grate* through which the ashes fall into the ash pit just below. The ashes must be removed regularly to allow air to reach the coal. Large amounts of oxygen are needed to burn coal properly. Some furnaces have an automatic coal-feeding device called a *stoker* which forces the coal into the furnace as it is needed and burns it with air blown in by a fan. The fuel is therefore burned more completely with a stoker than without one, and a much less expensive grade of coal can be burned. Furnaces operated by a stoker can also be controlled successfully by thermostats.

Fuel oil. Fuel oils are obtained from petroleum. Their heating value is nearly twice as great as that of an equal weight of coal. Oil is cleaner to handle and more convenient to store than coal. It burns with less smoke than coal and leaves no ashes. Fuel oil can be piped across the country to distribution centers at comparatively low transportation costs.

Two types of oil-burning furnaces are in common use. In the *pressure-gun burner,* oil is sprayed through a small hole, or *jet,* into the firebox and ignited by an electric spark when the burner is turned on. In other oil burners, the oil is carried to a burner by gravity. Like other types of furnaces, oil-burning furnaces should be cleaned and put in good condition each year. Cleaning and adjusting modern furnaces is a technical job which should be done by a qualified person.

Gaseous fuel. Two kinds of gas are used for heating purposes—natural gas and manufactured gas. More than three fourths of the gaseous fuel used in the United States is natural gas. As you will recall, natural gas is obtained from oil wells (see pages 86-87). It is collected from the wells in pipe lines and carried to distribution centers, from which it is piped to communities and thence to homes for use as fuel. *Manufactured gaseous fuel* is derived mainly from coal. When coal is heated in the absence of air, the gas given off is collected and stored in large tanks for distribution. Natural gas produces about 50 per cent more heat than

Diagram of a pressure-gun oil burner. Oil is sprayed through the nozzle and fired by an electric spark across the gap. Air is pumped through the air tube; the air and oil mix, producing a hot flame in the furnace.



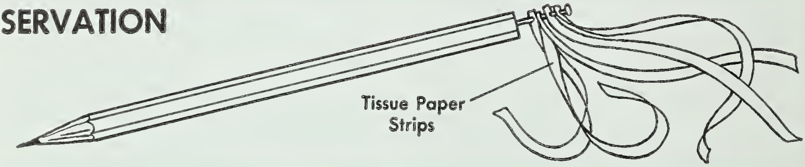
manufactured gas. Gaseous fuel has two important advantages over other types of fuel; it is more easily distributed to consumers, and it burns with little smoke and no soot or ashes.

In a gas-burning furnace, gas and air are admitted through small openings in the burner. While the furnace is in operation, a small gas flame called a *pilot light* burns continuously. When gas and air are admitted into the burner, the pilot light ignites the gas. The air intake is adjusted so that the proper amount of air enters the furnace to make the gas burn with a blue flame. If too little air enters, the flame is orange-yellow and smoky. If too much air enters, the flame will be extinguished. Much of the heat value of the gas is lost unless the flame is burning properly. The operation of a gas furnace can be effectively controlled by use of a thermostat.

SUMMARY

Heating systems in buildings depend upon conduction, convection, and radiation for transferring heat from its source in burning fuels. The efficiency of a heating system is determined by how completely and evenly the heat is transferred from its source throughout the building. Homes can be kept most comfortable with least cost when heat losses from conduction, convection, and radiation are reduced to a minimum. The suitability of a fuel for use in a heating system is determined by a number of factors, including (1) cost; (2) heat-producing qualities; (3) ease of transportation and storage; and (4) the amount of smoke, soot, and ash produced when it is burned. Heating systems should be inspected and adjusted periodically to insure most efficient operation.

OBSERVATION



What to observe. The action of convection currents in a heated room.

How to observe them. Attach the paper strips to a pencil as shown in the drawing. Hold the paper strips in several places in a heated room, such as around radiators and stoves or near open windows, where convection currents are likely to be present, and observe the action of the paper strips. (The smoke from a lighted punk is even more sensitive to convection currents, and if available can be used in place of the paper strips.)

Interpretation of your observation. Write one sentence which tells where convection currents are likely to be found in a heated room.

TEST YOURSELF

In the proper place on your answer sheet, write the letters of the ending which best completes each statement.

1. A simple fireplace heats a room primarily by (a) conduction; (b) convection; (c) radiation; (d) evaporation.
2. The most inexpensive furnace to install in a home is (a) pipeless; (b) forced hot-air; (c) hot water; (d) steam.
3. If 100 grams of steam at 100°C were changed to water without any change in temperature, the amount of heat released would be (a) 0 calories; (b) 540 calories; (c) 5,400 calories; (d) 54,000 calories.
4. A heating system which warms the room and its occupants by pipes in the floor, walls, or ceiling uses (a) convection currents; (b) radiant energy; (d) conduction; (e) evaporation.
5. Heat loss *cannot* be reduced by (a) installing storm windows; (b) using insulation in the walls and ceilings; (c) increasing the number of radiators in a room; (d) weather-stripping the windows and doors.

CHAPTER ACTIVITIES

TEST YOUR UNDERSTANDING

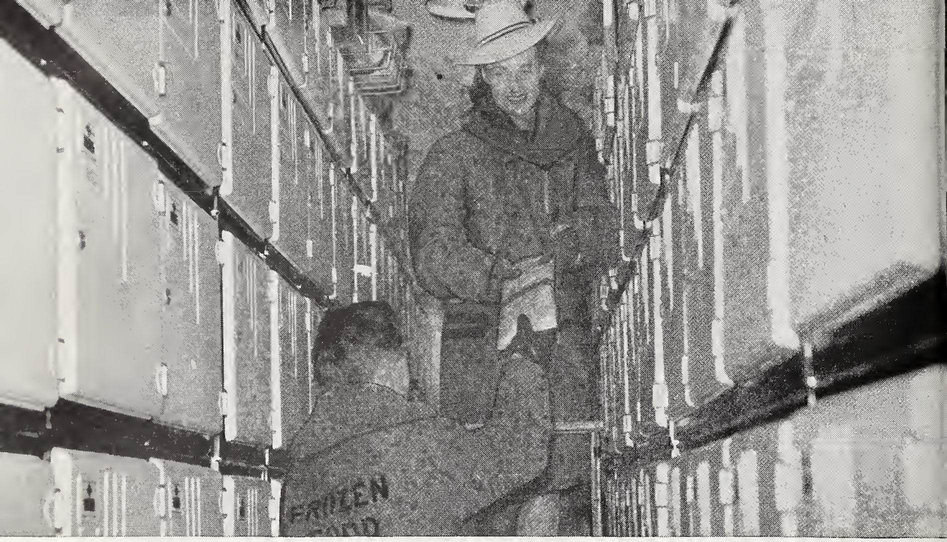
Two important generalizations developed in this chapter are listed below. Following each generalization is a list of statements each of which may or may not illustrate the application of the generalization. On your answer sheet, write the letters of those statements listed beneath each generalization which illustrate its application. **Do not write in your textbook.**

Generalization 1. We control heat in our homes by preventing its loss to the outside.

- a. Many homes are equipped with storm windows.
- b. Some homes are built of brick rather than of wood.
- c. Screens are usually installed on the windows of homes.
- d. Insulation is often placed between the outside and inside walls of a home.
- e. Oil is used as fuel for heating homes.
- f. Weather stripping is often placed around the windows and doors of homes.

Generalization 2. We control heat in our homes by transferring it from the heating unit to different parts of the house.

- a. In some heating systems there is a hot- and cold-air pipe for each room.
- b. A warm radiator sets up convection currents in the air inside a room.
- c. Every home should be equipped with a thermometer.
- d. Fireplaces frequently result in a loss of warm air.
- e. In a hot-water heating system, a pump is often used to force hot water through the radiators.
- f. The heating value of fuels is measured in Btu's.



General Electric

Compartments or lockers, like the one from which this couple is removing frozen foods, are located in large well-insulated buildings where the temperature is as low as the freezing compartment of a refrigerator.

chapter 14 COOKING AND COOLING FOOD

MANY of the home activities of the early pioneer family in this country centered around the fireplace. Food was cooked and water was heated over the same fire that warmed the house. During the long winter evenings, the fire in the fireplace was also a source of light.

Today, beside some kind of central heating system, a kitchen range, a water heater, and a refrigerator are practically necessities in our homes. These heat-controlling devices have added greatly to the comfort and the conveniences of our homes. In this chapter you will learn how heat is controlled, through the use of these devices, in order to cook and cool foods in our homes.

PROBLEM 1. How is heat controlled in cooking food?

METHODS OF COOKING

When you order roast turkey, boiled lobster, or broiled steak in a restaurant, you are not only telling the waiter what kind of meat you desire but are also stating the method by which the meat is to be cooked. Whatever the method of cooking, heat is transferred to the food by conduction or convection or radiation.

Boiling. In boiling food, heat moves from the burner to the water by conduction through the pan or pot. It is then distributed throughout the water by convection currents. From the water it moves throughout the food by conduction. Once the contents of the pan have begun to boil, application of additional heat will not cook a particular food in less time, because the food can never get hotter than it is at its boiling point. The way to boil foods quickly and economically is to heat them to the boiling point as rapidly as possible, then reduce the heat so that they boil gently but steadily.

Pressure cooking. If the boiling temperature of the water in which the food is cooked can be increased, the food will be cooked in less time. It is not difficult to raise the boiling point of water. As water boils, it becomes steam. If this steam is not allowed to escape from the pot, it exerts a pressure on the surface of the water, raising its boiling point.

Devices called *pressure cookers* have tight-fitting lids which prevent the steam from escaping before it has acquired a certain pressure. The pressure indicator can be set to release the steam at almost any pressure up to 15 pounds per square inch. With the increased temperature, foods are cooked very rapidly. Thus time is saved, and comparatively little fuel is needed for cooking.

Roasting and baking. Roasting and baking are done in an oven. The air in the oven is heated and moves throughout the oven by convection currents. The food is heated by the hot air in the oven. The walls of the oven must be well insulated to prevent loss of heat, and the interior should be designed to permit hot air to circulate evenly.

Frying. Food is generally fried in a metal or a glass pan. Heat from the stove moves by conduction to the bottom of the pan and thence to the food. Frying pans are usually made of metal because metals are good conductors of heat and do not break easily. Iron, aluminum, and copper are most often used. Of these metals, copper is the best conductor and iron the poorest. A frying pan with a thick bottom has two advantages. First, it has a large amount of metal to conduct the heat from the center to the edges, thus heating the pan evenly over its entire surface. Second, the bottom will remain flat when heated so that it will have complete contact with the stove. A pan whose bottom is thin is likely to bulge at the center when heated and thus not have the maximum contact with the stove. In such a pan, the food cooks unevenly.

For the greatest economy in frying foods with gas or electricity, each pan should be selected to fit the burner with which it is to be used. If the pan is too small, heat escapes around the side and is wasted; if it is too large, the food is not cooked properly.

Broiling. Food is broiled almost entirely with radiant energy. A bed of hot coals from an open fire is excellent for broiling food. Charcoal is also used. Both coals and charcoal give off large amounts of radiant energy. The food is placed near the coals and slowly turned as it becomes heated on each side. In electric ranges the food is placed below wires which are heated with electricity. In gas ranges it is placed just below the gas burner in the oven.

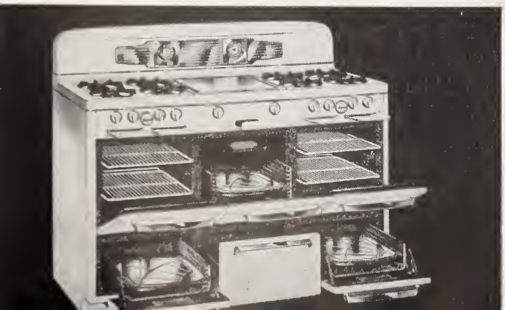
SOURCES OF HEAT

Cooking stoves or ranges. Ranges or cooking stoves are designed to use several different sources of heat. Ranges that burn wood or coal have several disadvantages. It is difficult to control the amount of heat produced. The entire stove becomes heated and raises the temperature of a whole room. Considerable effort is required to keep a wood or coal range fired and cleaned.

Some oil ranges burn kerosene. The burner on this type of range operates like that in a kerosene lamp. Oil on a saturated wick is burned as fuel. Although this type of oil stove is an improvement over the coal range, it has some disadvantages. A supply of wicks and oil must always be kept on hand, and smoking burners produce undesirable odors. Other ranges use gasoline as a fuel. Such ranges are used by the Army in temporary camps, and also by campers and picnickers.

A modern range cooks many different ways.

George D. Roper Corp.



The most convenient type of kitchen range uses gas or electricity as a source of heat. The burners or heating elements on the top of the stove are arranged so as to make them most effective in boiling or frying foods. On the better ranges, the ovens are well insulated so that very little heat is lost. Many of the ranges are equipped with automatic controls which regulate the amount of heat produced and the length of time foods will be cooked.

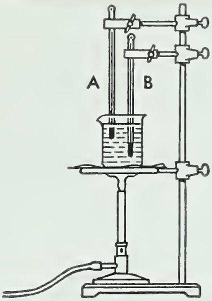
Water heaters. A source of hot water is a great convenience for cooking and cleaning purposes. Modern water heaters have many advantages over the old teakettle which was hung in the fireplace or placed on top of the coal range. Several types of water heaters are in use today, all operating on similar principles.

In most water heaters, the heating unit is controlled by thermostats so that water in the tank is kept at the desired temperature. The hot-water tanks are generally well insulated to prevent heat loss. Gas burners, electric heating elements, and oil burners are commonly used in automatic water heaters. In some water-heating systems the water is heated in coils inside the furnace as it is used; no storage tank is needed.

SUMMARY

Foods are cooked by use of devices to control the transfer of heat to them through conduction, convection, and radiation. An efficient range or water heater is one that transfers heat to food or water with the least heat loss.

EMONSTRATION



Generalization to be demonstrated. Water is heated by convection currents.

What you need. Two thermometers; a beaker; a Bunsen burner; a ringstand and ring; two burette clamps; a wire screen; wood shavings from pencil sharpener.

What to do. Set up the equipment, as shown above, putting cold water in the beaker and stirring in a few pencil shavings. Record the temperature of thermometers A and B before heating the water. Now heat the water in the beaker and record the temperature of A and B every 30 seconds until the water boils.

What to observe. 1. How do the thermometer readings change as the water is being heated?

2. How do the pencil shavings move as the water is being heated?

What does it mean? 1. How was heat distributed from water at the bottom of the beaker to water near the top of the beaker.

2. What evidence is there that convection currents are present in the water?

3. What is one basic assumption in this experiment?

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Potatoes can be cooked most rapidly if they are (a) boiled vigorously; (b) allowed to boil gently; (c) cooked in a pressure cooker; (d) boiled over an open fire.
2. The one characteristic which is *not* related to the effectiveness of a frying pan in cooking food well is the (a) thickness of the bottom; (b) material of which it is made; (c) flatness of the bottom; (d) height of the sides.
3. If food is cooked largely by radiant energy, it is said to be (a) boiled; (b) fried; (c) broiled; (d) baked.
4. To prevent heat loss from an oven, the walls of the oven should be (a) thick; (b) insulated; (c) enameled;

(d) placed as far from the source of heat as possible.

5. In a hot-water tank the water throughout the tank is heated by (a) radiation; (b) friction; (c) convection currents; (d) heating units that are placed at various points throughout the tank.

PROBLEM 2. How is heat controlled in cooling food?

COOLING EQUIPMENT

For many reasons, our homes today must be equipped with some means of keeping foods cool. Many kinds of food must be stored at low temperatures to prevent their spoiling. Fresh fruits and raw vegetables are more palatable when served cold. In hot weather, iced drinks are refreshing and are almost a necessity.

Cooling from melting. As you know, if cracked ice is placed in a glass of warm water, the temperature of the water falls rapidly as the ice melts. How do we explain the fact that melting ice will cool the material which surrounds it?

You have learned that the molecules of ice move more slowly than those of water (see page 30). When the speed of ice molecules is increased to a certain point, the molecules can no longer exist as ice but change to water. When ice is placed in warm water (or warm air), the fast-moving molecules of the warm water (or air) speed up the slow-moving molecules of the ice. The ice melts. But in melting the ice, the fast water (or air) molecules are slowed down. This results in the water (or air) being cooled. Thus ice melts by absorbing heat, thus cooling its surroundings.

Change of state. When ice melts to form water, there is a change in the arrangement, or *state* of the molecules. They move from a state in which they form a solid to one in which they form a liquid. The molecular state is again changed when water turns to steam. The molecular states in which matter can exist are known as solid, liquid, and gaseous states.

Changing from one state to another is either a heat-absorbing or a heat-liberating process. Experiments have shown that it requires about 80 calories to change one gram of ice from the solid to the liquid state. These 80 calories do not change the temperature; they are used to increase the speed of the ice molecules enough for them to move from the solid to the liquid state. Thus melting is a heat-absorbing process. On the other hand, when water freezes, it moves from a state of faster molecular speed to one of slower molecular speed, that is, from a liquid to a solid. In this case, about 80 calories of heat are given off for each gram of ice formed. Thus freezing is a heat-liberating process. The change in molecular activity necessary to move from a liquid to a gaseous state explains why boiling and evaporation are heat-absorbing processes while condensation is a heat-liberating process (see page 239).

Ice refrigerators. The cross section of a common type of ice refrigerator page 257 shows how cool air circulates in it. Examine the direction of the convection currents, and you will understand why the shelf immediately below the ice is the coldest part of the refrigerator. Foods such as milk, butter, and eggs that must be kept cold should therefore be placed just below the ice.

When ice is covered, it melts more slowly than when it is uncovered, and therefore lasts longer. But it is the melting that cools the refrigerator. Therefore, in order that ice may cool the refrigerator as much as possible, it should not be covered but should be allowed to melt freely.

Electric refrigerators. In the electric refrigerator a *freezing unit* serves the same purpose as the ice in the ice refrigerator. Convection currents are set up inside the food compartment, and the circulating air keeps the food cold. A simplified arrangement of the mechanism in an electric refrigerator is shown on page 258. A careful study of it will show you how the refrigerator operates.

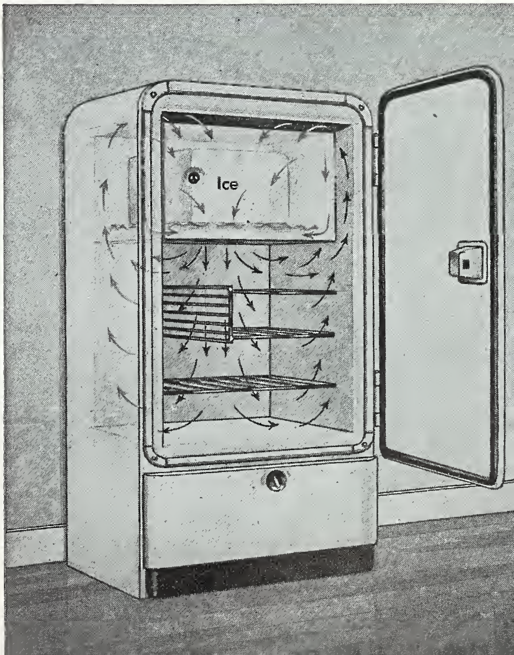
Water vapor in the refrigerator forms a layer of ice on the freezing unit. Since ice is a poor conductor of heat, it reduces the efficiency of the freezing unit. It should therefore be removed at short intervals by defrosting, that is, by disconnecting the freezing unit so that the ice may melt. This will help keep down the cost of operation. In some refrigerators, defrosting is automatic. The refrigerator should be in a cool place, and warm foods should be cooled to room temperature before being stored in it. Also, the door of the refrigerator should be opened as seldom as possible to prevent large amounts of cold air from escaping.

Ice is manufactured commercially by a process similar to the one used in electric refrigerators. Ammonia gas is used to lower the temperature of large tanks of salt water, or brine. Metal containers filled with water are suspended in the cold brine until the water freezes.

Gas refrigerators. The gas refrigerator is operated by a small gas flame directly above which is a small container filled with a mixture of ammonia gas, or some other material, and water. The heat from the gas flame drives some of the ammonia gas from the mixture. The ammonia gas then rises to the top of the refrigerator, where it cools and changes to a liquid. The liquid ammonia passes to the cooling unit, where it evaporates and absorbs heat. It is then forced back into the water above the gas flame.

Frozen food. When fresh food is frozen very rapidly, the water in the food freezes in such a way that the flavor of the food is affected very

As the ice melts, it absorbs heat from the surrounding air. The cooled air becomes heavier and falls to the bottom, forcing the warm air up. This action sets up convection currents.

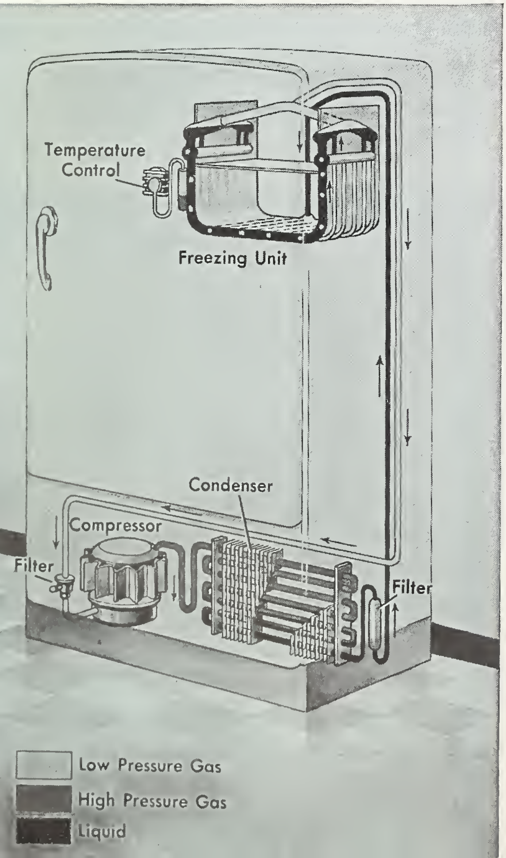


little. When the food is cooked, it tastes very much like fresh food. Almost every kind of fruit, vegetable, or meat can be purchased in the frozen-food markets. Food can also be frozen in home freezers. The freezing units operate on the same principle as the electric refrigerator.

Dry-ice refrigeration. Probably you have seen ice cream packed with cakes of *dry ice*. This is a solid form of carbon dioxide and is sometimes called *carbon dioxide snow*. It is made by cooling carbon dioxide gas until it becomes a liquid and then allowing the liquid carbon dioxide to evaporate rapidly. As the liquid evaporates, its temperature becomes so low (−78°C) that it forms flakes of carbon dioxide snow. The flaky material is then pressed into cakes and used for refrigeration purposes.

Dry ice is used in cooling many perishable foods, including ice cream, fruits, vegetables, and fresh meats. In several respects it is more satisfactory than ice, its chief advantages being that it has a much lower temperature than ice, it changes from a solid to a gas without becoming a liquid, and it absorbs three times as much heat as melting ice.

When the refrigerator operates, the compressor compresses the gas of a special chemical and pumps it to the condenser. There the gas cools and condenses, giving off heat. The liquid from the condenser passes through pipes to the freezing unit where it evaporates thus absorbing heat from, and cooling, the inside of the refrigerator.



SUMMARY

The state (gas, liquid, or solid) in which a substance exists is determined by the amount of movement of its molecules. A change of state requires a gain or loss of heat, depending upon the direction of the change.

Under ordinary conditions both ice and dry ice change state readily and absorb heat from their surroundings. They are therefore used in cooling foods. Electric and gas refrigerators are the most convenient type of refrigerator for household use because they are so constructed that the cooling material is used over and over again.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. When a solid changes to a liquid (a) the movement of its molecules has been decreased; (b) the movement of its molecules has been increased; (c) the weight of its molecules has been increased; (d) the weight of its molecules has been decreased.
2. An iced drink is cooled because (a) the ice placed in it is cold; (b) the ice in it melts; (c) heat is absorbed from the drink as the ice melts; (d) the ice makes the drink lose heat to the atmosphere around it.
3. In an electric refrigerator, a liquid changes into a gas in the (a) compressor; (b) condenser; (c) motor; (d) freezing unit.
4. Solid carbon dioxide is called dry ice because it (a) is colder than ice; (b) changes directly to a gas as it absorbs heat; (c) absorbs more heat than ice does; (d) is made from liquid carbon dioxide.
5. An example of a heat-absorbing process is (a) water freezing; (b) steam changing to water; (c) ice melting; (d) hot water cooling.

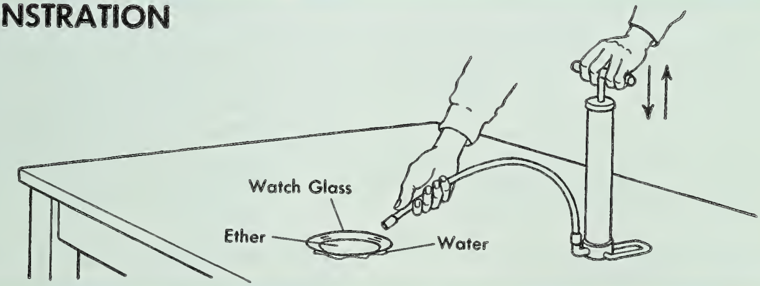
OBSERVATION

What to observe. The release of heat from an electric refrigerator while it is running.

How to observe it. Locate the network of tubes and metal fins, called the condenser, on an electric refrigerator. It is usually on the back of the refrigerator. Feel the condenser at different places while the refrigerator is running.

Interpretation of observation. After studying the diagram on page 258, write one sentence describing the reason the condenser is warm.

EMONSTRATION



Generalization to be demonstrated. A liquid absorbs heat when it evaporates.

What you need. A small watch glass; ether; water; tire pump.

What to do. Set the watch glass containing a small amount of ether in a few drops of water on a wooden table top. Pump a stream of air steadily against the surface of the ether. Make the air stream as strong as possible without blowing the ether out of the watch glass. (**Caution:** Avoid breathing large amounts of the ether fumes.) As soon as the ether has evaporated, pick up the watch glass.

What to observe. What has happened to the water around the watch glass?

What does it mean? How does what you have observed demonstrate the generalization?

Basic assumptions in this demonstration. 1. The only way the water lost heat was through the evaporation of the ether.

2. All liquids act like ether when they evaporate.

CHAPTER ACTIVITIES

HOW IS HEAT CONTROLLED?

Two important generalizations developed in this chapter are listed below. Following each is a list of statements which may or may not illustrate the application of the generalization. On your answer sheet, write the letters of those statements which illustrate the application of the generalization under which they are listed. **Do not write in your textbook.**

1. Cooking is accomplished by controlling the transfer of heat from some source to the food being cooked.
    a. Some cooking utensils are made of stainless steel with a layer of copper on the bottom.
    b. Insulating material is placed in the walls of an oven.
    c. Cooking ranges are often enameled white.
    d. The handles of many cooking utensils are made of wood.
    e. Foods cooked in a pressure cooker are heated by steam.
    f. A cast-iron plate is sometimes placed just above the flame on a gas range so that the food will cook more evenly.
2. You can cool food by controlling the transfer of heat to and from it.
    a. Meat will soon spoil if it is not kept cold.
    b. The walls of a refrigerator are insulated.
    c. The inside of a refrigerator is usually enameled.
    d. A liquid expands to a gas inside the freezing unit of an electric refrigerator.
    e. A gas changes to a liquid in the condenser outside of the box of an electric refrigerator.
    f. Although an ice refrigerator should be well insulated, the ice should be permitted to melt.

SELECT HYPOTHESES

Below are three statements related to the control of heat for cooking and cooling food. Beneath each statement are three hypotheses, one of which reasonably explains the statement. On your answer sheet, write the letter of the hypothesis which you think best explains each statement.

Statement 1. A housewife noticed that whenever she used the oven on her stove, the kitchen became very warm.

a. The oven was being operated at too high a temperature.
b. The oven door was open.
c. The oven was not completely insulated.

Statement 2. Some fishermen were camping at a high altitude in the Rocky Mountains. They found that even though dried beans were boiled for several hours, the beans did not become as soft as when they were cooked at home.

a. They used the wrong kind of beans.
b. The fire was not hot enough to make the beans soft.
c. The boiling water was not hot enough to make the beans become soft.

Statement 3. A housewife baked a layer cake in two tins, one of which was dark from long use, and the other a new shiny one. When the cake was removed from the tins, she found that the layer of cake in the dark tin had a heavier, darker crust than the one in the shiny tin.

a. The cake dough in the two tins was different.
b. The tins were heated to a different temperature in the oven.
c. The dark tin absorbed more radiant energy from the oven than the shiny tin did.

UNIT ACTIVITIES

APPLY YOUR KNOWLEDGE OF HEAT

A number of generalizations related to heat are listed below. A number of situations in which heat plays an important part are listed after the generalizations. For each of the situations listed, select one generalization that will explain the situation, and write its number in the proper place on your answer sheet.

GENERALIZATIONS

1. Dark, rough, or unpolished surfaces are better absorbers of radiant energy than light, smooth, or polished surfaces.

2. When electricity overcomes resistance it produces heat.

3. Most materials expand when heated and contract when cooled.

4. Heat is absorbed when solids change to liquids and when liquids change to gases, but is given off when the change is in the reverse direction.

5. Heat is transferred by conduction, convection, and radiation.

6. Materials differ in their ability to conduct heat.

SITUATIONS

a. Snow melts faster in places where it is dirty than where it is clean.
b. The heating element in an electric toaster is made of high-resistance wire.
c. A steam burn is often more serious than a burn from boiling water.
d. A pitcher of lemonade will be

cooled more by ice than by an equal amount of ice water.

e. Tropic explorers often wear helmets painted white.

f. Concrete pavement has cracks in it filled with a compressible material such as asphalt.

g. Many birds puff or ruffle their feathers in cold weather.

h. The floor feels colder than the rug even though both are the same temperature.

i. The heating units on an electric stove may become red hot.

j. Wet clothing may make a person feel uncomfortably cold even on a warm day.

k. Glass dishes sometimes break when hot water is poured on them.

CONSTRUCT DIAGRAMS OF MODELS

1. Different types of heating systems
2. A thermostat
3. A home showing where heat-saving devices should be used
4. Methods of heat transfer in cooking food in a double boiler
5. A refrigerator cooled by evaporation of water from cloth-covered sides.

VISIT PLACES TO LEARN ABOUT HEAT

1. A refrigerator repair shop to learn how refrigerators are constructed and repaired
2. A home that is being built to see what provisions are being made for insulation
3. A bakery to see how the ovens are heated and operated
4. A cold-storage locker to see how it is kept so cold

PREPARE REPORTS

1. Low temperature research in cryogenic laboratories
2. Calorimeters and their use
3. High-temperature furnaces
4. Thermometry through the ages
5. Solar heat for homes
6. Methods of cooking in different countries
7. The frozen-food industry
8. The use of bottled gas as fuel
9. Automatic cold- and hot-drink dispensers

READ ABOUT HEAT

Compton, Ray, and Nettels, Charles H., editors. *Conquest of Science.* New York: Harcourt, Brace and Company, 1939.

In a section entitled, "Over-heated Water" (pages 150–168), the story of how James Watt invented the steam engine is told in a manner you will find most interesting.

Crouse, William H. *Understanding Science.* New York: Whittlesey House, McGraw-Hill Book Company, Inc., 1948.

Includes an explanation of heat and its relationship to changing the state of matter on pages 24–28.

Mason, Bernard S. *The Junior Book of Camping and Woodcraft.* New York: A. S. Barnes and Company, 1943.

Includes excellent material on how to build different kinds of camp fires, cook food with camp fires, and keep foods cool in camp, on pages 46–72 and 84–104.

Ratcliff, J. D., Editor. *Science Yearbook of 1946.* Garden City, New York: Doubleday and Company, Inc., 1946.

In Chapter IX, "Heat from Cold," the way in which new-type heat pumps may revolutionize home air-conditioning is discussed.

U. S. Weather Bureau

Clouds indicate the condition of the atmosphere above the surface of the earth. The condition of the atmosphere determines our weather. These clouds promise fair weather.

unit 7 WEATHER AND CLIMATE

THE loss of life and property from a flood, a hurricane, or an airplane crash, the crop failures that follow a drought or untimely frost, and a forest fire caused by lightning are all examples of disastrous results of unfavorable weather conditions. Snow for winter sports, clear skies, and warm days for outings, and clear visibility for flying are examples of favorable weather conditions which determine the things we can do. You probably can recall disappointments you have experienced because the weather did not turn out to be what you had hoped.

The climate of a locality is determined by the different kinds of weather it has over a period of years. Weather and climate are closely related, and they affect our lives in many ways, as you can see. Since little can be done about changing either the kinds of weather or the climate where we live, it is necessary for us to adjust our activities to them. In order to make better adjustments to changes in weather, it is necessary to know when the weather will change, and what it will be like after it changes. Accurate weather forecasts, therefore, help us adjust to changes in the weather. But before weather scientists can make accurate forecasts, they need to understand what conditions determine weather changes and how to measure these conditions.

People living in a particular climate have learned how to protect themselves and their property from the kinds of weather that occur most frequently in that climate. They have also learned what kinds of activities, either for recreation or for making a living, are most suitable for the climate in which they live. A study of this unit should help us to understand better the things which determine weather and climate and how we can adjust to weather and climate.

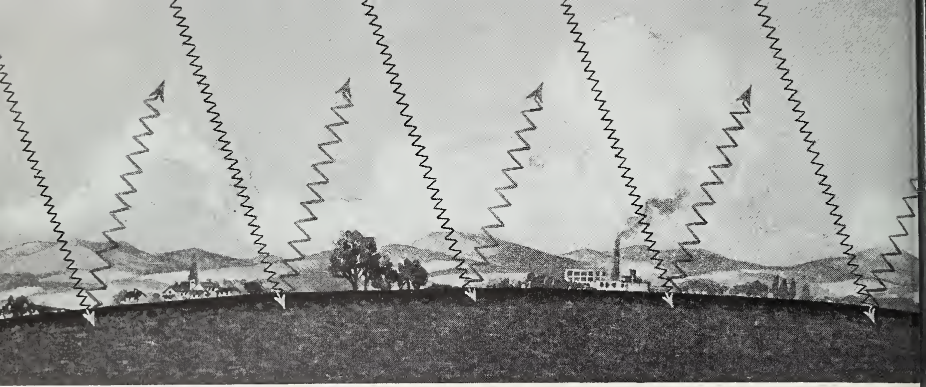
U. S. Weather Bureau

The shiny beads of water that you see on these clover leaves are dew formed from the water vapor in the air surrounding the leaves.

chapter 15 DETERMINERS OF WEATHER AND CLIMATE

WE HAVE learned that we live at the bottom of an atmosphere that extends some five hundred miles above the surface of the earth. Life on this earth planet has become dependent upon the atmosphere. It absorbs some of the higher frequency radiations from the sun that would harm us. The oxygen it contains is essential for the chemical processes that keep us alive. Our very act of breathing is made possible by the pressure it exerts. We could not exist without it.

Although all of our activities are carried on within a relatively thin layer of this invisible gas, the day by day changes in it have a great effect upon our lives. In this chapter you will learn how changes in the atmosphere come about; how these changes account for different kinds of weather; and how the climate of any locality, in turn, is determined by its weather.



The earth is heated by radiant energy from the sun. The warmed earth gives off radiant energy of a lower frequency than that which the earth received from the sun. The lower-frequency radiant energy heats the atmosphere more than the higher-frequency radiant energy from the sun.

PROBLEM 1. How do changes in the atmosphere cause different types of weather?

HEATING THE ATMOSPHERE

As the surface of the earth becomes heated by radiant energy from the sun, it in turn gives off radiant energy of lower frequency than that which it received. This radiant energy warms the atmosphere more than the higher frequency radiant energy from the sun. The atmosphere near the surface of the earth is therefore warmer than that farther above it.

Uneven heating effects. Several conditions affect the amount of heat produced at the earth's surface by radiant energy from the sun. The number of hours of daylight affects the amount of radiant energy which any part of the earth receives. Wherever there are clouds, dust particles, and smoke in the air less radiant energy reaches the earth. As you will recall from Unit 3, when rays of radiant energy strike the earth at a slant, the surface is heated less than when they strike it vertically. You have also learned that dark-colored surfaces such as soils and rocks are heated more by radiant energy than light-colored surfaces. Water surfaces are heated more slowly by radiant energy than land surfaces. It is evident, therefore, that some parts of the earth and the atmosphere above are heated more than others.

CONDENSATION OF WATER

Moisture is constantly evaporating from bodies of water and moist surfaces on the earth. The air near the surface of the earth therefore contains water vapor. When the air is holding as much water vapor as it possibly can at a certain temperature, a very small drop in temperature may cause the water vapor to condense. It will form droplets of water in the air only when there are tiny particles of material such as dust or smoke suspended in the air. When there is very little water vapor in the air, the temperature will have to be lowered much more before it condenses. The temperature at which the vapor can condense is called the *dew point*. When the temperature of the air is lowered to its dew point, water may form a cloud or fog, or it may be returned to the surface of the earth in the form of dew, frost, snow, rain, or hail. Water that falls to the earth as rain, as snow, or as hail is called *precipitation*.

Formation of fog, dew, and frost. The cooling of a large body of air near the surface of the earth to a temperature below its dew point may result in a fog. A fog is formed when the invisible water vapor in the air condenses on particles to form extremely small visible droplets which remain suspended in the air near the surface of the earth.

At night plants, other objects, and the ground itself often lose much of their heat, becoming cooler than the surrounding air. When the temperature of these objects drops below the dew point of the air, water vapor in the air immediately surrounding them may condense as *dew* on the objects (see picture, page 265). When the dew point of the air is below 32°F, water vapor in the air may change directly from a gas to solid ice crystals as *frost*. Before frost will form on an object, the temperature of the object must also be below 32°F.

Clouds, rain, and snow. When rising air containing sufficient water vapor is cooled below its dew point, clouds are formed, provided that there are particles in the air around which tiny droplets of water or crystals of ice or snow can collect. Whether droplets of water or ice crystals collect depends upon the temperature. Rain may result when tiny droplets of water combine, or when warm air enters the cloud from below and the water vapor in it condenses on the droplets already present. Tiny snow crystals grow when additional water vapor condenses on them. Rain or snow begin to fall only after the droplets or flakes become too heavy to remain suspended in a cloud.

Before snow reaches the earth, air temperatures between the earth and the cloud must be cold enough so that snowflakes do not melt as they fall. The air below the cloud must also be moist enough so that the snowflakes or rain will not change back into water vapor.

Formation of hail. *Hail* is usually formed when large drops of water are carried from a lower to a higher part of a cloud that extends to very high levels where temperatures are below freezing. As each drop of water reaches the colder cloud levels, snow and frost are added to it. It then falls, but soon stronger currents of air may carry it up again to freezing layers of the cloud where more snow and frost are added. Each time the growing hailstone falls and is returned to the colder part of the cloud, another layer of ice is added until it becomes too heavy to be suspended by updrafts of air and falls to the earth.

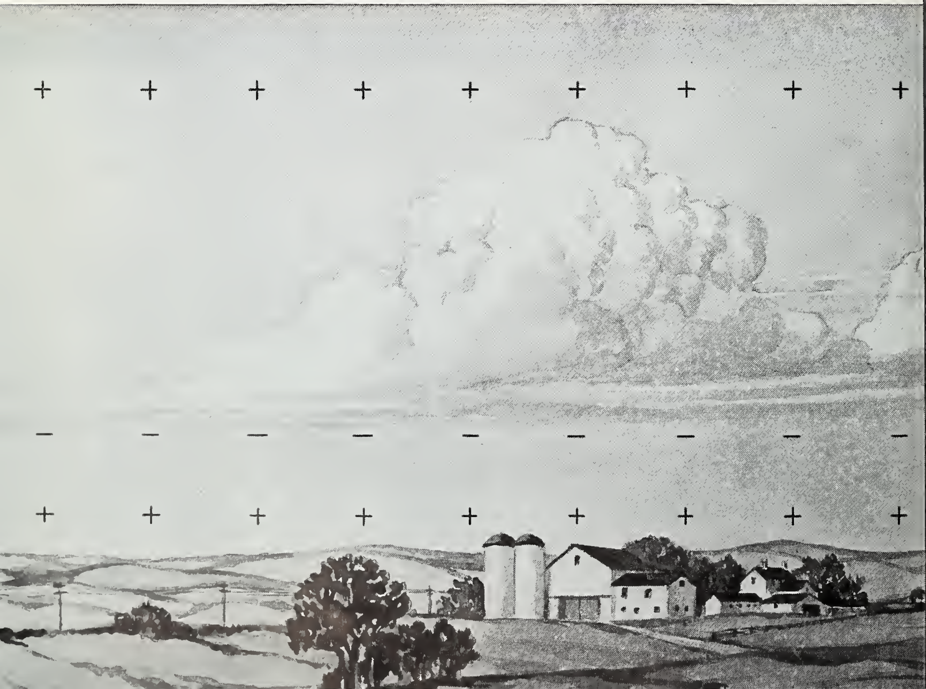
Thunderstorms. When the temperature of air near the surface of the earth is much higher than the temperature of air above it, warm air containing much water vapor rises rapidly. The cloud producing a *thunderstorm* develops from this rapid upward movement (see page 280). Warm summer afternoons when the air contains considerable water vapor are the best times for the formation of clouds that may produce thunderstorms. A thunderstorm does not generally cover much territory. Lightning, thunder, rain, and sometimes hail accompany it. The drawing below shows how the cloud becomes electrically charged. As rain forms in the upper parts of the cloud, the raindrops are broken up into finer particles by the strong upward rush of air from below. This produces static electric charges in the clouds.

An electrically charged cloud may cause objects on the earth beneath it to become oppositely charged. When the electric charges on the earth and the cloud become sufficiently great, lightning will flash between them. It is then said that lightning "strikes" the earth. High buildings, trees, and other tall objects are more frequently "struck" by lightning than nearby lower objects.

WINDS AND UNEVEN HEATING

Development of winds. Whenever any land surface absorbs more radiant energy from the sun and thus becomes warmer than surfaces of land surrounding it, a movement of air or wind results. The air covering the cooler surface is heavier and has greater pressure than the air covering the warmer surface of the earth. The cooler air having greater pressure moves along the surface of the earth toward the warmer air of less pressure. This movement of air across the surface of the earth is wind. If pressure differences between two bodies of air are great, violent winds may result.

It takes longer for radiant energy to raise the temperature of water than to raise the temperature of land. But since



When electric charges are built up on a cloud as shown below, the surface of the earth becomes positively charged. When charges on the cloud become sufficiently great they cause a large spark to break through the air to another cloud or to the earth, thus forming lightning.

bodies of water will hold more heat, they take longer to cool. If you have spent much time at ocean or lake shores, you have probably noticed that a cool breeze generally blows from the water toward the land during the day. At night the breeze blows from the land toward the water. During the day, the land is warmer than the water in the lake. The air over the land is thus warm and light, whereas the air over the water is cooler and heavier. The air over the lake, having greater pressure, moves along the surface toward the land and pushes the warm land air upward. This warm low-pressure air then moves toward the lake at levels above the cold air. Over the lake it becomes cooled and slowly sinks toward the surface of the water. Thus the air circulates from lake to land and back again during the day. At night the direction of air flow is reversed, since the land becomes cooler than the water in the lake.

Tornadoes. *Tornadoes,* which are whirling storms made up of violent winds, usually form in thunder clouds above the surface of the earth in a manner not clearly understood. They first appear as funnel-shaped clouds with the pointed end extending toward the earth (see right).

A tornado's path is generally not more than a fourth of a mile wide and 20 to 40 miles long. The tornado moves forward in a general northeasterly direction at a speed of about 30 miles an hour and can damage an area a quarter of a mile wide and a half a mile long in less than one minute's time. In the United States, tornadoes occur most frequently in the central and southeastern states during the spring and early summer.

U. S. Weather Bureau

A typical funnel-shaped tornado cloud. This tornado has done its damage and is lifting. It disappeared soon after this picture was taken.

Tropical cyclones. Areas of low atmospheric pressure may develop as a result of heating during the late summer and autumn in the tropical regions near the equator. These low-pressure areas may develop into storms called *tropical cyclones.* In such a cyclone, winds blow in a revolving *counterclockwise* motion (in a direction oposite to that in which hands of a clock move) around the relatively calm air at the center of the low-pressure area. The

Empire State Building Corp.

An unusual photograph showing lightning striking the TV antenna of the Empire State Building, New York City. This may occur several times during a thunderstorm.

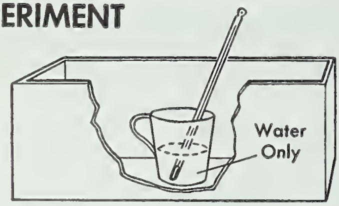
wind frequently reaches speeds of over 100 miles an hour. Tropical cyclones in the Northern Hemisphere move westward from their origin at from 10 to 30 miles an hour. After traveling several hundred miles they may curve northward.

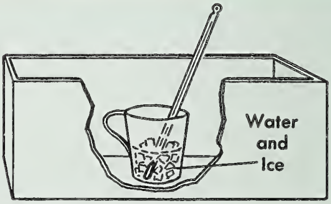
Tropical cyclones are called *hurricanes* in the West Indies, *typhoons* in the Western Pacific, and *cyclones* in the Indian Ocean. They are destructive storms, accompanied by heavy rain in addition to strong winds.

SUMMARY

The earth is heated unevenly by radiant energy from the sun. Since the atmosphere is warmed primarily by radiant energy from the heated earth, the temperature of the atmosphere over different earth surfaces is not the same at any one time. Changes in temperature change the capacity of the atmosphere to hold water vapor, thus making it possible for water to be evaporated and later to be condensed as precipitation. Differences in temperature result in differences in atmospheric pressure which cause winds and storms.

EXPERIMENT





Question to be answered. How cold must a polished metal cup be before water vapor from the air will condense upon it?

What you need. Two polished metal cups, two thermometers, ice, two stirring rods, two cardboard packing boxes.

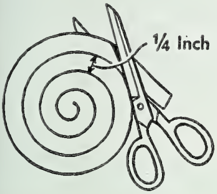
What to do. Half fill each metal cup with water at room temperature, and place each in an open-topped cardboard packing box of the same size. Add small pieces of ice to the water in one of the cups. Stir the water in both cups until droplets of water are visible on the outside of the cup containing ice. Check the temperature of water in each cup and compare.

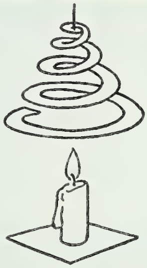
Your answer. What was the only difference between the two cups? Why were the cups placed in cardboard boxes? What was the temperature of the water in each of the cups at the time droplets of water appeared on the one with ice? How much was the temperature of the water lowered? Would you expect to get the same results if you did this experiment on another day? Would you expect general science pupils in another town to get the same results as you did? Why didn't water in the cup without ice have droplets form on it? How do you know that droplets of water did not come from the water in the cup? In one sentence write an answer to the experimental question. In your sentence make sure that you limit your answer to the air which you were using in this experiment.

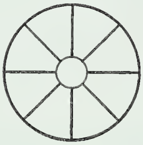
Some basic assumptions. 1. The cup which had contact with the air was the same temperature as the water in it.

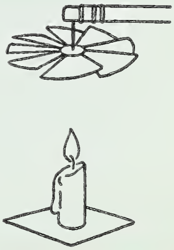
2. The air trapped in the boxes was no different from the air outside.

BSERVATION









What to observe. The effects of warm air rising.

How to observe it. In your text you have read that warm air rises above the colder air surrounding it. Since air is invisible, it cannot be seen moving upward as it is warmed. There are several interesting ways, however, of observing the effects of it as it moves upward.

Cut out a circular disk about 3 inches in diameter from a sheet of paper. Draw spirals on it, as shown in the diagram. Each spiral should not be more than ¼ inch wide. Cut out the spiral and suspend over a candle as shown. Observe the movement of the spiral.

On construction paper draw circles, as shown in the diagram. Trim the edges of the larger circle to form a disk. Draw four diameters equally spaced. Cut along each of the 8 lines from the edge of the disk to the inner circle. Bend each section to form a pin wheel. Suspend the pin wheel over a candle or some other source of heat by running a pin through the center and attaching it to a string or sticking it into a pencil eraser. You may have to make several of these pin wheels before you get one that is properly balanced. The results are worth the effort, however.

Interpretation of your observation. Why was each of the above suspended over some source of heat? Did you see warm air rising? In one sentence answer the question: How did you know warm air was rising? Have you seen other examples of this?

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Small droplets of water that remain suspended in the air near the surface of the earth are called (a) fog; (b) clouds; (c) rain; (d) dew.
2. When the dew point of air is below 32°F, water vapor in clouds may form (a) hail; (b) snow; (c) sleet; (d) frost.
3. Drops of water which are carried several times through a layer of air that is below 32° F. fall to the earth as (a) sleet; (b) hail; (c) snow; (d) rain.
4. Winds are caused by the movement of air from (a) a low- to a high-pressure region; (b) north to south; (c) a high- to a low-pressure region; (d) a warm to a cool region.
5. A storm accompanied by a whirling funnel-shaped cloud is known as a (a) cyclone; (b) hurricane; (c) tornado; (d) thunderstorm.

PROBLEM 2. What determines climate?

THE NATURE OF CLIMATE

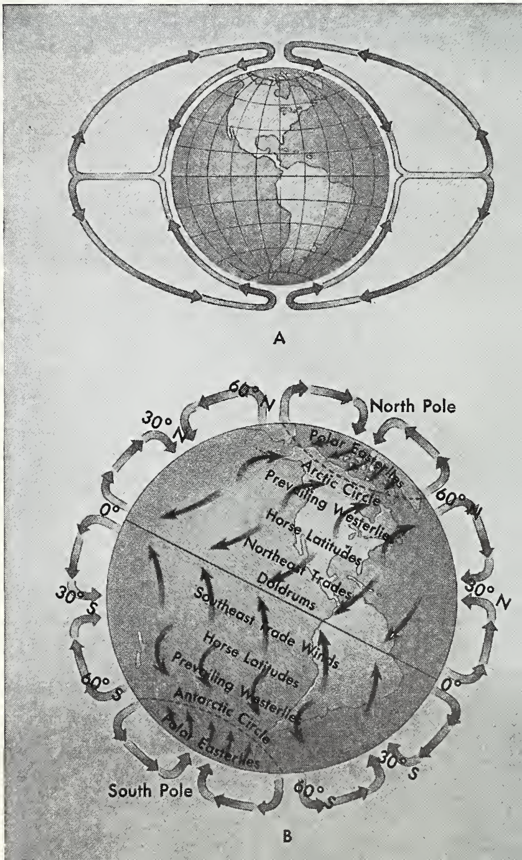
The climate of any place is determined by the types of weather it has. The types of weather are determined by the conditions of the atmosphere as it circulates over the earth.

Circulation of the atmosphere. We have seen how uneven heating of the earth's atmosphere causes various types of storms. It also causes the atmosphere to circulate between the equator and poles of the earth in a manner similar to that shown in the drawing on page 273. Although the arrows in B indicate that there is regular flow of air in definite patterns, land areas interfere with this circulation pattern near the surface of the earth. But over the ocean and at altitudes above the interference of the land, the air generally circulates in the patterns shown.

If you refer to A and B as you read the following, you will understand better how the atmosphere circulates over the earth. Because the sun's rays striking the earth at the equator are less slanted, air at the equator is heated more than the air north or south of the equator. The heated air expands and becomes less dense. The cooler heavier air north and south of the equator is under greater pressure than the air at the equator. The heavier air, therefore, moves toward the equator, forming the *trade winds,* which force the lighter equatorial air up. Since the air along the equator is rising, a belt of calm air is formed, called the *doldrums.* After the warm air rises over the doldrums to high altitudes, it spreads out and begins to flow toward the north and south poles. The air continues to move poleward until it reaches latitudes about 30°N and 30°S. It then descends to the earth for reasons not completely understood, forming another belt of calms called the *horse latitudes.* The descending air, when it reaches the surface of the earth, spreads out. Some of it flows toward the equator as trade winds, but the remainder flows toward the poles to form winds called the *prevailing westerlies.* This air, when it reaches latitudes about 60° N and 60° S, is forced up by cold heavier air moving down from the poles as the *polar easterlies.* After this air has risen to high altitudes, some of it moves toward the poles; the remainder moves toward the equator, descending to the earth in the region of the horse latitudes.

Effect of earth's rotation upon direction of prevailing winds. You probably wonder why the winds of the earth generally blow from an easterly or westerly direction rather than directly north or south. There is an explanation. Let us begin with the northeast trade winds to explain it. The distance around the earth is greater at the equator than at any position north or south of the equator. You know that the earth rotates from west to east upon its axis once every 24 hours. Points near the equator move faster than points north of it. The atmosphere over the horse latitudes in the Northern Hemisphere moves eastward at the same speed as the surface of the earth beneath it. When this air descends and starts flow-

The arrows in A indicate how the atmosphere over the earth would probably circulate if the earth were not tilted and did not rotate. The arrows in B show the pattern in which it actually does circulate.



ing south, it is not moving in an eastward direction as fast as the surface of the earth over which it is now flowing toward the equator. The southward moving air, therefore, lags behind and flows in a southwest direction. But because the air flows *from* the northeast, the winds are called northeast trade winds. For the same reason the trades in the Southern Hemisphere flow from the southeast and are called southeast trades.

Let us see if this is also the explanation of the direction in which the prevailing westerlies flow. The surface of the earth at the horse latitudes in the Northern Hemisphere is moving east faster than the surface of the earth north of the horse latitudes. Therefore the atmosphere over the horse latitudes is also moving faster. When air flows north from the horse latitudes over the surface of the earth, it is therefore moving in an eastward direction faster than the land surface. The air, therefore, tends to flow *from* the southwest, and the winds are called westerlies. The direction in which the westerlies of the Southern Hemisphere flow can be explained in the same manner.

Average weather in belts of winds and calms. The doldrums are a belt of calms because there are no winds for about one fourth of the time. When winds do blow, they are generally only light breezes and may blow from any direction. The rising warm air results in frequent thunderstorms and rain in the doldrums.

The trade winds, blowing from an easterly direction toward the equator, are rather constant over the ocean but very irregular over bodies of land. Regions over which the trades blow generally have clear weather. Light winds, which may blow from any direction, and frequent calms occur in the horse latitudes, where clear skies, dry air, and little rainfall are typical of the weather.

The westerly winds are irregular both in strength and the direction from which they blow. Because they blow from a westerly direction more often than from any other direction, they are called prevailing westerlies. Most of the United States is in this belt of many types of weather.

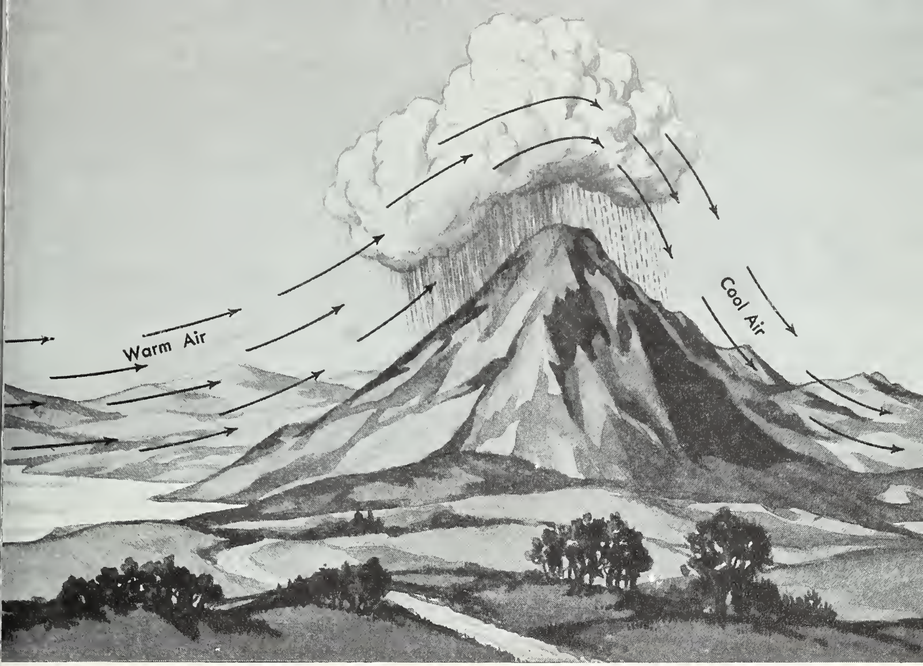
The weather conditions described as typical of the belts of winds and calms are average weather conditions. For most of the time and in most places within the belt, the weather will be quite similar to that described.

CONDITIONS AFFECTING CLIMATE

Altitude. The atmosphere at higher altitudes is less effective in preventing heat losses from the surface of the earth. Therefore places located at high altitudes generally have cooler climates. You can see on page 275 how high mountains affect precipitation.

Bodies of water. Another factor in climate is the distribution of water over the surface of the earth.

Since the temperature of water changes more slowly than that of land, bodies of water such as large lakes, seas, or oceans tend to keep the temperature of nearby land areas more even. Generally the winters and summers along the seacoast are less severe than those in the interior of a continent. Land areas near the ocean receive more precipitation than those farther inland. The farther you go from the ocean into the interior of a continent, the less rainfall and the more extreme temperatures you may find.



Warm air moving across bodies of water, such as shown at the left, contains a relatively large amount of water vapor that has evaporated from the surface of the water. As long as the air remains warm, it will hold the water as a gas or vapor. Whenever the warm air moves up the slope of a mountain, it cools and the vapor condenses into droplets of moisture forming clouds. As the air is cooled within the cloud, larger droplets of water form and rain falls. The cooled air, as it moves down the opposite slope of the mountain, becomes warmer and again picks up more water vapor.

Ocean currents and climate. Currents of ocean water also affect the climate of land bodies along which they flow. The prevailing winds and other forces cause the water to move in regular currents.

One such warm ocean current flows north along the eastern coast of the United States and then across the Atlantic Ocean to northern Europe, making the climate of those areas warmer than it would otherwise be. Both warm and cold ocean currents affect the climate in many other places throughout the world.

SUMMARY

The climate of any locality is a history of its weather. The location of a place in the pattern of atmospheric circulation over the earth largely determines the type of climate it will have. Its climate may be modified, however, by altitude, mountain ranges, nearness to large bodies of water, and ocean currents.

TEST YOURSELF

In the proper place on your answer sheet write the letter of the ending which best completes each statement.

1. Most of the United States lies in the belt of winds known as (a) prevailing westerlies; (b) prevailing easterlies; (c) polar easterlies; (d) trade winds.
2. The belt of calm air nearest the equator is called the (a) trade winds; (b) horse latitudes; (c) doldrums; (d) prevailing westerlies.
3. The climate of a locality is least affected by (a) circulation of the atmosphere; (b) altitude; (c) people living there; (d) nearby large bodies of water.
4. Clear skies, dry air, and little rainfall are typical of the weather (a) in the doldrums; (b) in the horse latitudes; (c) in areas over which the trades blow; (d) near mountains.
5. The wind belt immediately north or south of the doldrums is called (a) the horse latitudes; (b) a belt of calms; (c) trade winds; (d) prevailing westerlies.
6. Winds do not move directly north or south over the surface of the earth because (a) the earth rotates from west to east; (b) large areas are covered by ocean; (c) large mountain ranges interfere; (d) they do not have sufficient force to cause them to blow toward the poles.

CHAPTER ACTIVITIES

WEATHER AND CLIMATE

You have learned that the day-to-day atmospheric changes at any one place are known as its *weather,* while its *climate* is determined by the types of weather it has. Listed below are a number of situations which are thought to be closely related to either the weather or climate of any locality. On your answer sheet, write a **W** for those situations most directly accounting for weather, and a **C** for those having greatest influence upon climate. **Do not write in your textbook.**

1. A sudden change in air pressure
2. Trade winds
3. A rapid change in air temperature
4. The high altitude in mountain ranges
5. General circulation of the earth's atmosphere
6. Condensation of moisture in the air
7. Ocean currents

MAKE AN OUTLINE

In order to make an outline, one should be able to pick out the most general topics or ideas from what he hears and reads. He should then be able to associate the other topics or ideas to the general ones. In the following list of topics, there are three general topics to which the others may be related. Select these three and write them on your answer sheet. Then write each of the other topics under the general topic to which it is most closely related.

1. Types of storms
2. Circulation of atmosphere
3. Thunderstorm
4. Determiners of climate
5. Altitude
6. Rain
7. Fog
8. Cyclone
9. Winds
10. Snow

U. S. Forest Service

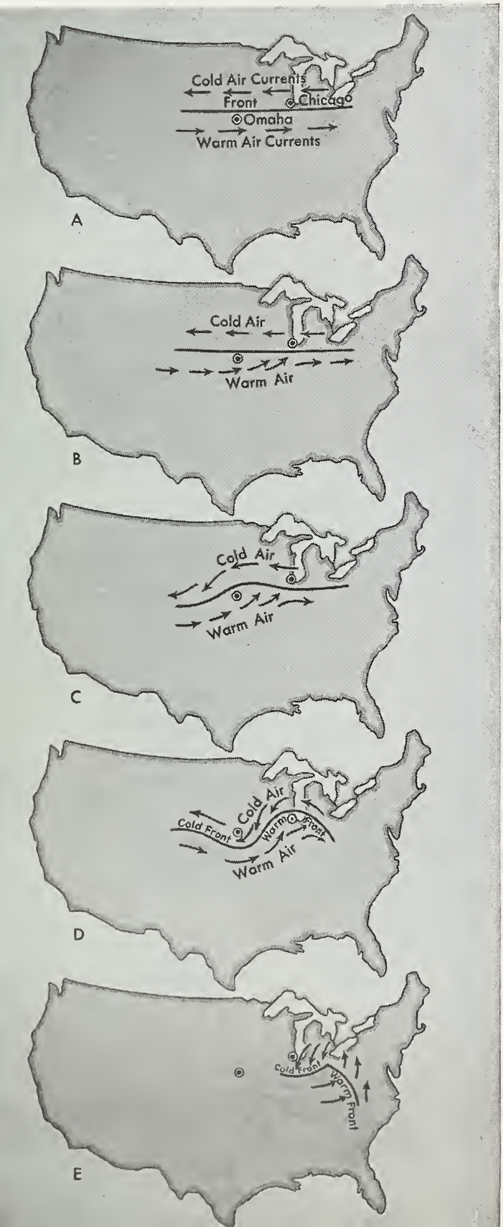
A woman lookout in one of our national forests taking weather readings.

chapter 16 MAN'S ADJUSTMENT TO WEATHER AND CLIMATE

THE kind of weather we will have tomorrow or the day after depends not only upon the condition of the atmosphere where we live, but also upon atmospheric conditions in other places as well. In order to predict weather changes weather forecasters, called *meteorologists,* must know what the atmosphere is like at many different places and altitudes over the earth. They must also know in what direction the air is moving, the speed with which it is moving, and how it may be changed as it moves. Because scientists have learned so much about the weather and can pass the information along to us, we are able to adjust ourselves to changes in weather. We can prepare ourselves for weather to come, and dress and house ourselves comfortably. This shows one very definite way in which science touches our daily lives.

PROBLEM 1. How do we attempt to forecast the weather?

The development of a wave cyclone along the fronts between masses of cold and warm air.



THE EFFECT OF AIR MOVEMENTS

Air masses near the earth's surface. Most of our changes in weather are associated with the movement of large bodies of air, called *air masses,* which are made up of either cold or warm air. Cold air masses form over water or land surfaces on the earth that are cold, whereas warm air masses form over water or land surfaces that are warm. Cold air masses are generally quite shallow, but warm air masses may become 5 or 6 miles deep. Air masses may become several hundred miles wide. Cold air masses which enter the United States form over northern land or water areas, and warm air masses form over land or bodies of water in the southern part of North America.

If the air masses remained in the regions where they were formed, they would have little effect upon the weather in the United States. But they do not. As more cold air is added to a developing cold air mass, it becomes larger and larger and begins to move southward toward the United States. Warm air masses grow in a similar manner over warm southern regions, and enter the United States from the south. Because of the westerly winds, both the cold and warm air masses generally move eastward across the country.

Development of cyclonic storms. Cold air masses moving in from the north and warm air masses coming in from the south meet as they move across the United States. The surface of air separating the two masses is called a *front.* Such a front in the region of Omaha and Chicago is shown as A in the drawing at left. In B, warm air currents have been turned toward the cold air mass, setting up a wave as shown in C. The wave moves from west to east under the influence of the prevailing westerlies located at higher levels. That portion of the wave where colder air replaces warmer air at the ground is called a *cold front*. The *warm front* is that portion of the wave where warm air replaces cold air at the ground. The wave action in D may increase until it reaches its greatest development, as shown in E.

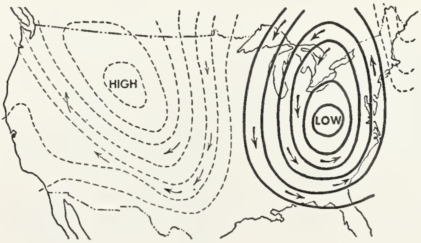
As the two fronts are bent into a deepening wave, clouds form where the warm air is lifted up the gently sloping warm front (see page 278). Thunder clouds may form where the warm air is forced up suddenly ahead of the bulge in the advancing cold front. The clouds are formed as the warm moist air rises to levels where its water vapor begins to condense. As the water vapor changes into more compact droplets of water or ice crystals, it takes up less space, thus producing a center of low pressure. The air surrounding this center of low pressure turns inward toward it, thereby beginning a great circular movement of air. As it begins to rain or snow, the pressure continues to drop and more and more air moves into the center of lowering pressure. This wave in the air is now whirling to the left (counterclockwise), in the Northern Hemisphere, around a center of low pressure. Accompanied by clouds and rain, it moves eastward across the United States as a *cyclonic storm.* Meteorologists refer to them as *extra tropical cyclones, wave cyclones,* or *lows.* A drawing of a low as it might appear from a weather map is shown at right. As you can see, the action of cold and warm air in a low causes changes in the weather.

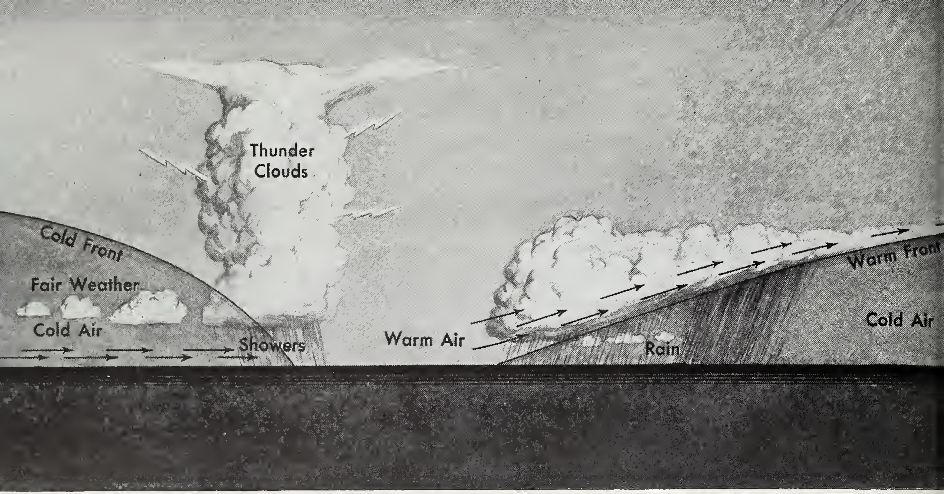
Highs usually follow lows. Lows moving across the United States are usually followed by another spiraling movement of air called a *high* or *anticyclone.* Whereas the center of a low is a low-pressure area, the center of a high is a high-pressure area. The centers of lows are characterized by ascending air currents and highs by descending air currents. Highs usually bring fair or partly cloudy weather.

Winds aloft. So far we have considered air movements and changes near the surface of the earth as they affect weather. But meteorologists have discovered that what is happening in the atmosphere at very high altitudes *(aloft)* also affects earth-bound weather. The pattern and nature of winds at altitudes of 30,000 to 40,000 feet are quite different from those nearer the earth's surface. The velocities, or speeds, of winds aloft are very high. One such band of wind, called the *jet stream,* blows at velocities up to 200 miles an hour. The directional patterns of winds aloft are not the same as the earthly winds beneath them.

The movement of most storms is guided largely by winds aloft. The

Broken lines drawn between places of equal pressure indicate a high, heavier lines a low. Arrows show the direction of air currents.





Whenever a cold air mass meets a warm air mass along a cold front, the colder heavier air pushes under the warm air and abruptly forces it up, producing showers, generally thunderstorms, as shown at the left. When advancing warm air overtakes the cold air mass, as shown at the right, the warm air slides up and over the cold air and forms a warm front, causing rain.

upper air may also develop its own cyclonic waves which may result in clouds and rain. For a cold front to be strong, the surface winds must be blowing harder into the bulge of the front than the winds aloft. Otherwise, these high-altitude winds might move the earthly mass of warm air aside before it is lifted by cold air to form clouds and rain. The higher winds, at other times, might reinforce the winds below, contributing to thick cloud formation and heavy precipitation. There are a number of other ways in which winds aloft may affect atmospheric conditions here on the earth.

COLLECTING WEATHER INFORMATION

Since our weather may originate at different levels in the atmosphere, weather observers carefully study the atmosphere from the earth up as high as they can make observations. A knowledge of the changes that occur from day to day at the various levels helps to determine in advance what the weather might be. The weather observer spends much of his time determining air temperature, air pressure, amount of water vapor in the air, and the direction and velocity of air flow at different altitudes.

Weather observing stations are located in thousands of different places throughout the United States. Most of the stations are operated by volunteer observers, but more than 300 of them have a regular staff of observers.

Weather ships are maintained for observing atmospheric conditions in the Atlantic and Pacific Oceans. Commercial and military aircraft and specially equipped weather airplanes are used to observe atmospheric conditions at high altitudes. Arctic weather observing stations are maintained by our government. We also share weather information with many other countries.

Air temperature. Several different kinds of thermometers are used by weather observers to measure air temperature. The "minimum thermometer" is used to register the lowest temperature during any period of time. It is constructed so that the liquid in the thermometer forces a marker down as the air temperature decreases. The marker then remains at its lowest position. The "maximum thermometer" is used to record the highest air temperature for any period of time. In this thermometer, as the liquid rises with higher temperatures, a marker is pushed along with the liquid, and remains at its highest position. The markers are reset with a small magnet.

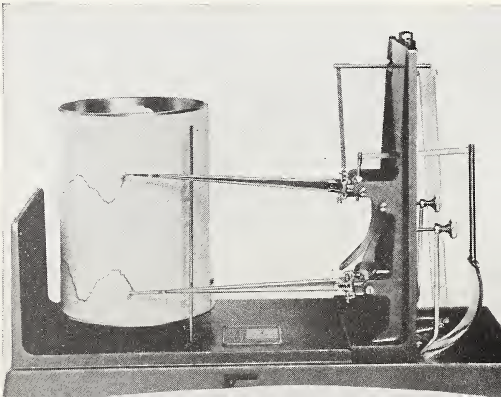
Some weather observers take readings once each hour or so with an alcohol or mercury thermometer. If a continuous record of air temperature is desired, the *thermograph* may be used. This instrument, shown at right, below, keeps a complete record of daily temperature changes.

Atmospheric pressure. Weather observers use the mercury *barometer* to obtain the most accurate measurements of atmospheric pressure. A glass tube closed at one end is filled with mercury. It is then placed in a container of mercury with the closed end of the tube at the top and the open end of the tube below the level of the mercury in the glass container. The mercury in the tube falls until the weight of the mercury in the tube is equal to the atmospheric pressure on the surface of the mercury in the container. The space above the mercury in the tube contains practically no air. Whenever the atmospheric pressure increases and decreases, the height of the mercury in the tube rises and falls. In the United States one way of measuring atmospheric pressure is by the inches of mercury in the tube supported by the atmospheric pressure. In countries where the metric system of measurement is used, air pressure is measured in millimeters (mm.). When the barometer records 29.92 inches or 760 mm., it means that the pressure of the atmosphere supports a column of mercury 29.92 inches high. Another unit called the *bar* is now used by meteorologists for measuring air pressure. Since the bar is a unit of pressure rather than a unit of length, it is more suitable for measuring air pressure. The United States Weather Bureau measures atmospheric pressure in millibars[1] (1/1000 of a bar), and weather maps are published with the pressure indicated in millibars.

The *barograph,* used by the weather observer to get a continuous record of air pressure, operates in much the same

Hygro-thermograph, combination hygrograph and thermograph, with cover removed. The lower marker moves up and down with changes in relative humidity and the upper marker records air temperatures the same way.

U. S. Weather Bureau



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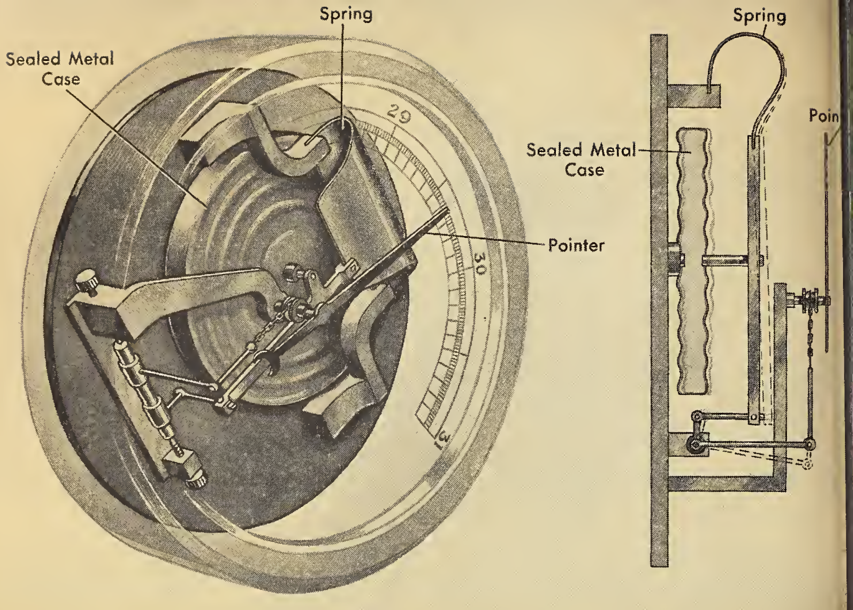
[1] 1050 millibars equals 31 inches of mercury.



In the aneroid barometer some of the air has been removed from the sealed metal case. An increase in atmospheric pressure forces the sides in, whereas a decrease allows the sides to push out. As shown in the side view, these slight movements are transmitted to the pointer by a system of levers, thus registering changes in atmospheric pressure.

way as the thermograph. A pen attached to the end of a metal arm records the pressure on a revolving chart. The metal arm is attached to an *aneroid barometer* (see drawing, above) so that the arm moves up and down as the air pressure changes.

Water vapor in the air. Both the actual amount of water vapor in the air and the amount of water vapor which the air can hold are used in describing the humidity of the air. *Absolute humidity,* the actual amount of water vapor in the air at any one time, is expressed in grams of water vapor per cubic meter of air. *Relative humidity* is the amount of water vapor the air actually contains as compared with the total amount it could hold at any one temperature. Relative humidity is expressed in percentages. When the air is holding all the water vapor it can at a given temperature, it is *saturated.*

Relative humidity as well as dew point can be determined by using an instrument called a *psychrometer.* This consists of two thermometers mounted on a frame that can be whirled rapidly in the air. The bulb of one thermometer is covered with a thin piece of cloth. This bulb is dipped into water before being used and is therefore called the *wet bulb.* The psychrometer is then whirled in the air. After several minutes the temperature registered by each thermometer is recorded. The *dry-bulb* thermometer registers the temperature of the air. The wet-bulb thermometer will usually register a lower temperature because of the cooling effects of the evaporation of water from its surface. The less water vapor in the air, the more rapidly water evaporates, and the lower will be the temperature recorded by the wet-bulb thermometer. Thus the difference between the temperatures recorded by the wet- and dry-bulb thermometers depends upon the amount of water vapor in the air. After obtaining the difference, both the relative humidity and the dew point can be read from specially prepared Psychrometric Tables.

To keep a continuing record of relative humidity, weather observers use the *hygrograph.* It operates like the thermograph and the barograph. The recording arm of the hygrograph is attached to a hair. Since hair lengthens and shortens with changes in the humidity, the arm moves up and down and the pen records the changes on a chart. (See page 281.)

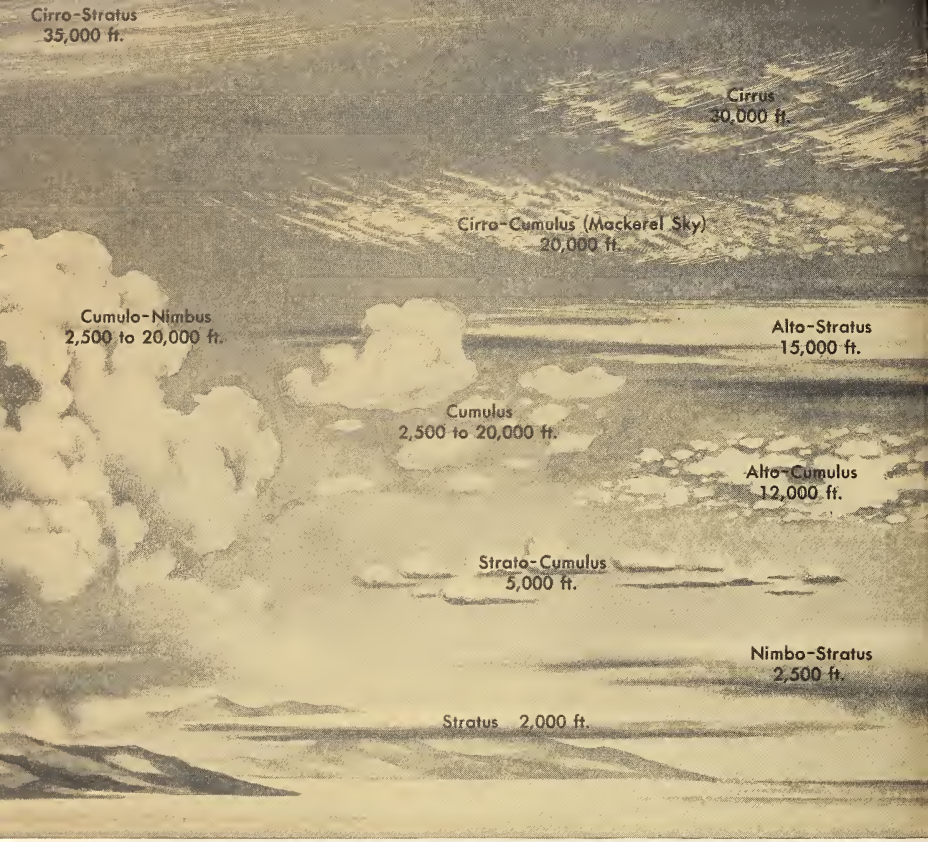
Air movements. The weather observer keeps accurate records of the speed of the wind and the direction from which it blows. *Wind vanes* are used to determine the direction of the wind. *Anemometers* are used to measure the speed of the wind. One type consists of cups mounted on an axle which turns with the wind. In order to get accurate measurements of the direction and speed of wind, the wind vane and anemometer must be located where there are no obstructions.

Winds have been classified in terms of their speed. The Beaufort Wind Scale at the bottom of the weather map on page 285 is used by observers to describe winds in their weather reports.

Cloud observations. Clouds are an indication of the condition of the atmosphere at various levels above the surface of the earth. They are formed when the temperature of the air becomes low enough to cause the water vapor in the air to form tiny water droplets or ice crystals (see page 267). Clouds have been classified into ten different groups based upon their appearance and the atmospheric conditions of the cloud. They are *cirrus, cirro-cumulus, cirro-stratus,* classified as *high clouds* because of the height at which they are found; *alto-cumulus* and *alto-stratus,* called *middle clouds;* and *strato-cumulus, stratus, nimbo-stratus, cumulus,* and *cumulo-nimbus,* called *low clouds.* The cloud formations and the altitudes at which they are usually found are shown on page 284.

Precipitation. All weather observers measure precipitation, using a rain gauge, and keep daily records of it. The simplest type of rain gauge is a pan with straight sides perpendicular to the bottom. The pan is placed in the open, and after a rain the amount of precipitation is measured by the depth of the water in the pan. Weather observers use a standard rain gauge with an opening in the top exactly eight inches across, as shown at the left on page 277. The water which enters the top part of the rain gauge runs into a long tube where it can be measured. Since the measuring tube is somewhat smaller than the top of the rain gauge, each inch of water in the tube represents only 1/10 of an inch of actual rainfall.

In determining the amount of precipitation in snow, one inch of snow is about equal to 1/10 inch of rain.


Cirro-Stratus
35,000 ft.
Cirrus
30,000 ft.
Cirro-Cumulus (Mackerel Sky)
20,000 ft.
Cumulo-Nimbus
2,500 to 20,000 ft.
Alto-Stratus
15,000 ft.
Cumulus
2,500 to 20,000 ft.
Alto-Cumulus
12,000 ft.
Strato-Cumulus
5,000 ft.
Nimbo-Stratus
2,500 ft.
Stratus 2,000 ft.

Clouds have been classified into ten different types based upon their appearance and atmospheric conditions in the cloud. Note the altitudes at which the different types of clouds are commonly formed.

Atmospheric conditions above the surface of the earth. Since it is now possible to fly airplanes at altitudes of 30,000 to 40,000 feet, they are being used to obtain information about atmospheric conditions at those altitudes. The *radiosonde* is an instrument used by a ground observer to measure atmospheric conditions at various altitudes. This instrument is attached to a helium-filled balloon that carries it to altitudes as high as fourteen miles. The way that this instrument is used is shown in the picture on page 286.

Small *pilot balloons* may be used to determine the direction and speed of the wind at different altitudes. These small rubber balloons, filled with helium, are released from the ground, and their movements in air currents are observed by means of instruments on the ground.

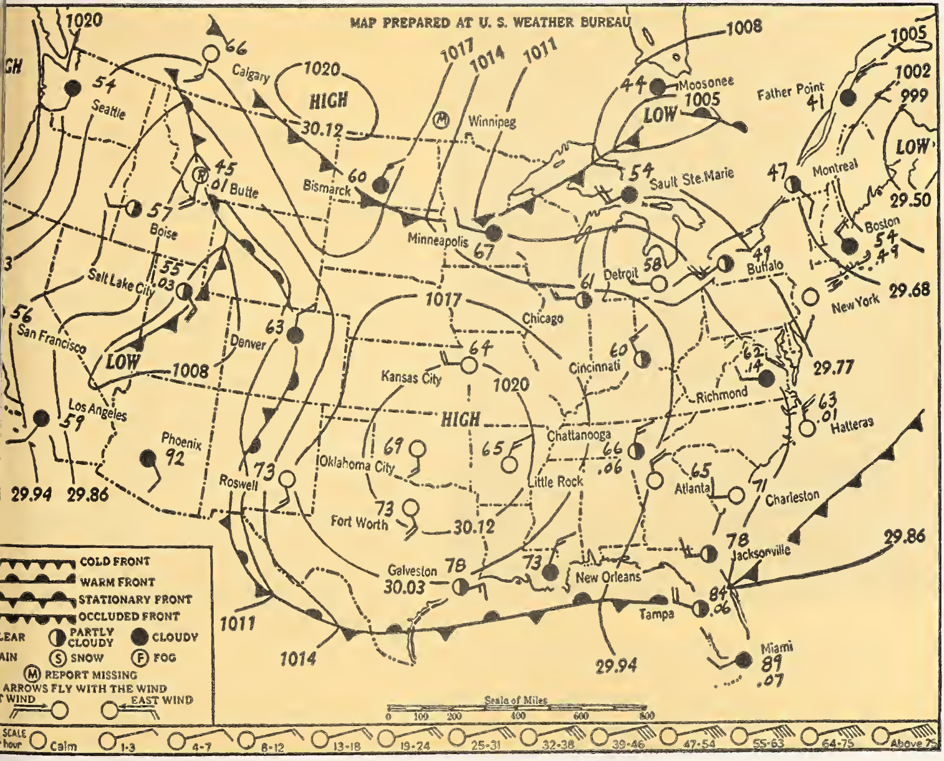
Low altitude observations of the balloons are made with an instrument called the *theodolite*. The movement of pilot balloons at altitudes as high as 19 miles can be determined by using radar. When radar is used, a metal target is attached to the pilot balloon to reflect the radio waves.

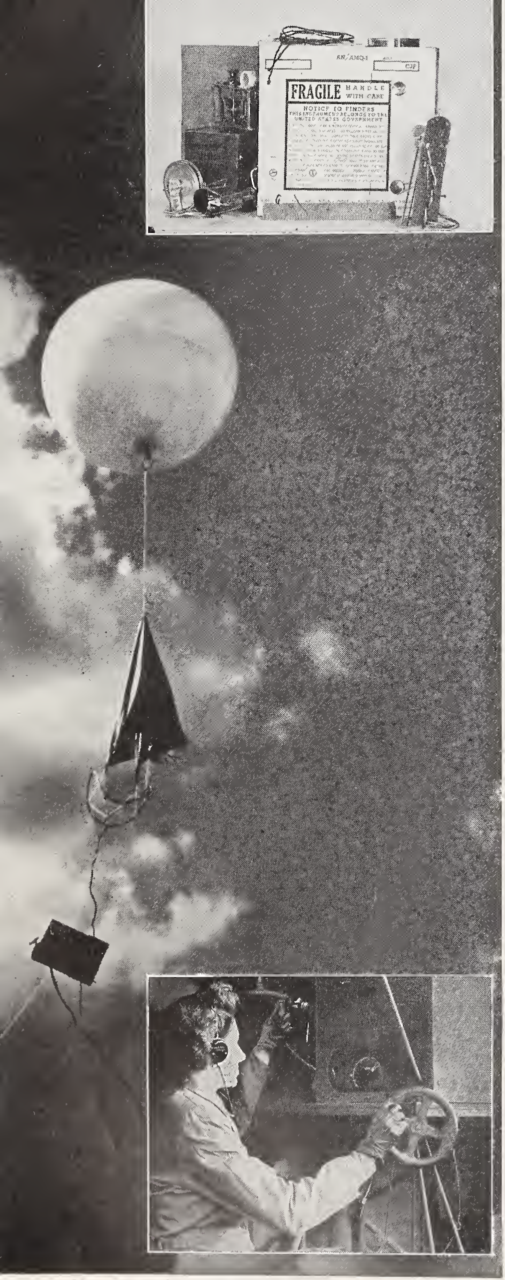
Forecasting weather. Official weather observers make their observations of atmospheric conditions at the end of every six-hour period during the day. Daily reports from many different observers on land and at sea are sent to district forecasting centers which are under the supervision of the United States Weather Bureau. In each forecast center, as soon as reports from the weather-observing stations are received, the information is recorded in such a manner that the forecaster has a summary of the atmospheric conditions at different levels for as high as observations have been made. The summary of atmospheric conditions near the earth is prepared in the form of a weather map, such as shown below. From all of this information, and based upon his knowledge of what might happen when a certain combination of atmospheric conditions are present, the forecaster predicts what the weather will be like 24 hours hence.

Because of the great variety of conditions that determine what tomorrow's atmosphere will be like, there is not sufficient time for any forecaster to compute mathematically all possibili-

Weather map of the United States. The solid lines called *isobars,* connect places having equal atmospheric pressure. It is reported in millibars as well as in inches of mercury. The other numbers indicate temperature and inches of rain.

U. S. Weather Bureau





U. S. Weather Bureau

Radiosonde in flight, showing balloon, parachute, and instrument. In the upper picture are shown the measuring instruments and the radio for transmitting information to the observer on the ground, shown at bottom.

ties and then select the most likely one. He must take many short cuts and make the best possible guess based upon his experience. Sometimes he misses, although he more often gets it right.

A computing machine, one of those "mechanical brains" which you may have heard about, has been built which can work millions of such mathematical weather problems in less than an hour. The machine is being tried out by the United States Weather Bureau and, by the time you read this sentence, it might be in regular use. The use of this machine makes possible *numerical weather forecasting*. Information from observers is "fed" into the computer which has been set to solve the millions of problems necessary to predict air movements over the next 24 hours. In less than an hour, it turns out predictions which can be used to make wind charts. By using these charts, the forecaster can predict tomorrow's weather with greater certainty.

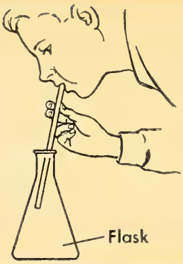
Weather proverbs and signs. Before man understood the many different conditions that cause weather changes, he attempted to use simple signs such as the position and appearance of the moon and the planets as a means of predicting the weather. There is no evidence today to support such ideas. February 2 is sometimes listed on calendars as "Groundhog Day," because at one time it was believed that the groundhog came out from his burrow that day. If it was a clear day and he saw his shadow, he would return to his burrow, since he knew there would be six more weeks of bad weather. You have probably heard many other such stories about animals being able to predict weather. Like human beings, animals are sensitive to present weather conditions, but there is no evidence that any animal is sensitive to weather changes which have not yet occurred. Weather proverbs such as "rain before night, sailors delight," and "rain in the morning, sailors take warning," should also be analyzed carefully to determine whether they have any relationship to the actual conditions that bring about weather changes.

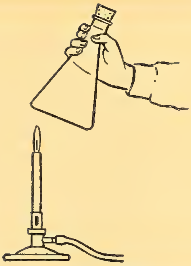
Daily weather forecasts published in calendars for a year in advance are not dependable, for they are based upon an average of the types of weather over a period of years. Because so many different conditions cause weather of any one type, it is only by chance that a forecast made a whole year in advance is correct.

SUMMARY

What tomorrow's weather will be depends upon changes that will take place in the atmosphere. In order to predict those changes, it is necessary to obtain information about atmospheric conditions throughout the country and at different altitudes as high as observations can be made. Instruments have been developed for accurate measurement and recording of atmospheric conditions. Computing machines give promise of more accurate weather prediction in the future. Weather proverbs and signs and long-term forecasts should be carefully judged in light of our present knowledge of weather—what it is and how it happens to change.

EMONSTRATION





Generalization to be demonstrated. The capacity of air to hold water vapor depends upon the temperature of the air.

What you need. Flask; stopper to fit flask; Bunsen burner or other source of heat; glass tube 6 inches long.

What to do. Clean the flask and be sure that it is dry both inside and out. Put it in a cold place until it is thoroughly cold. Insert the glass tube into the flask and blow through it gently until a film of moisture collects on the inside wall of the flask. Place the stopper tightly in the flask, then warm the flask gently and observe what happens to the moisture. After the flask has been warmed, again place it in the cold place and observe it regularly.

What to observe. 1. What happens to the film of moisture inside the flask as it is heated?

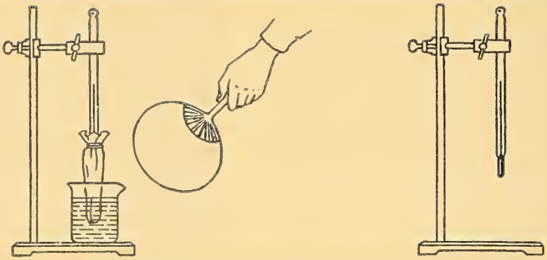
2. What effect does cooling the warm flask have upon the water vapor in the air inside the flask?

What does it mean? 1. How does heating and cooling the air inside the flask affect its ability to hold water vapor?

2. How do temperature changes affect the ability of the atmosphere to hold water vapor?

A basic assumption. The total atmosphere acts in the same way as the air inside the flask does.

EXPERIMENT



Questions to be answered. How does the use of open pans of water in the classroom affect the relative humidity?

What you need. Two Fahrenheit thermometers; cotton cloth; ringstand; two burette clamps; beaker or water glass; water; tape; several shallow pans about 12 inches wide.

What to do. In this experiment it will be necessary to use your own science classroom and another classroom near it. Furthermore, it will be necessary to start the experiment one day and complete it a few hours later or even the next day. Determine the relative humidity in your classroom and in the other room by proceeding as follows:

1. Wrap a piece of cotton cloth about 1 inch wide and 4 inches long around the bulb of one thermometer, as shown. Support both thermometers with the clamps on the ringstand. Record the readings of the two thermometers. Place some water in the beaker, dip the cloth in it until it is thoroughly wet, and place the beaker on the ringstand so that the lower end of the cloth hangs in the water. Fan both thermometer bulbs until there is no further change in the one with the wet cloth on it. Record the readings of both thermometers. Subtract the thermometer readings, being careful to consider any difference in reading which may have been present at the be-

ginning of the experiment. Using the difference in reading obtained, look in the table below and work out the relative humidity of the two rooms.

2. Fill the pans with water. Place them on or near the radiators in your classroom and leave them there until your next class period. Remember the only difference between the two rooms should be the pans of water. What other conditions will have to be controlled? During your next class period, determine the relative humidity in the two classrooms.

What to look for. How does the relative humidity in the two rooms compare? What were the controls in this experiment? Were they adequate?

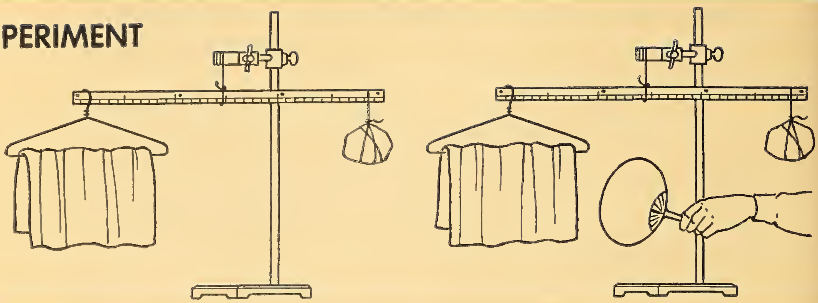
Your answer. In one sentence, write an answer to the above question. Would you feel better about your results if you could repeat the experiment?

Assumptions. What assumptions did you have to accept in arriving at your answer?

PER CENT RELATIVE HUMIDITY

AIR TEMPERATURE (DRY BULB FAHRENHEIT)	DIFFERENCE BETWEEN TEMPERATURE RECORDED ON DRY-BULB AND WET-BULB FAHRENHEIT THERMOMETERS																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
65	95	90	85	80	75	70	66	62	57	53	48	44	40	36	32	28	25	21	17	13	10	7	3							
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22	18	15	11	8	5	1						
67	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	30	27	23	20	16	13	9	6	3						
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28	24	21	17	14	11	8	4	1					
69	95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32	29	25	22	19	15	12	9	6	3					
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26	23	20	17	13	10	7	4	1				
71	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31	27	24	21	18	15	11	8	5	3				
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28	25	22	19	16	13	10	7	4	1			
73	95	91	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33	29	26	23	20	17	14	11	8	5	2			
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21	18	15	12	9	7	4	1		
75	96	91	87	82	78	74	70	66	63	59	55	51	48	44	41	38	34	31	28	25	22	19	16	13	11	8	5	2		
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35	32	29	26	23	20	17	14	12	9	6	4	1	
77	96	91	87	83	79	75	71	67	63	60	56	52	49	46	42	39	36	33	30	27	24	21	18	15	13	10	7	5	2	
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37	34	31	28	25	22	19	16	14	11	9	6	4	1
79	96	91	87	83	79	75	71	68	64	60	57	54	50	47	44	41	37	34	31	29	26	23	20	17	15	12	10	7	5	2
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44	42	38	35	32	29	27	24	21	18	16	13	11	8	6	4
82	96	92	88	84	80	76	72	69	65	62	58	55	52	49	46	43	40	37	34	31	28	25	23	20	18	15	13	10	8	6
84	96	92	88	84	80	77	73	70	66	63	59	56	53	50	47	44	41	38	35	32	30	27	25	22	20	17	15	12	10	8
86	96	92	88	85	81	77	74	70	67	63	60	57	54	51	48	45	42	39	37	34	31	29	26	24	21	19	17	14	12	10
88	96	92	88	85	81	78	74	71	67	64	61	58	55	52	49	46	43	41	38	35	33	30	28	25	23	21	18	16	14	12
90	96	92	89	85	81	78	75	71	68	65	62	59	56	53	50	47	44	42	39	37	34	32	29	27	24	22	20	18	16	14
92	96	92	89	85	82	78	75	72	69	65	62	59	57	54	51	48	45	43	40	38	35	33	30	28	26	24	22	19	17	15
94	96	93	89	86	82	79	75	72	69	66	63	60	57	54	52	49	46	44	41	39	36	34	32	29	27	25	23	21	19	17
96	96	93	89	86	82	79	76	73	70	67	64	61	58	55	53	50	47	45	42	40	37	35	33	31	29	26	24	22	20	18
98	96	93	89	86	83	79	76	73	70	67	64	61	59	56	53	51	48	46	43	41	39	36	34	32	30	28	26	24	22	20
100	96	93	90	86	83	80	77	74	71	68	65	62	59	57	54	52	49	47	44	42	40	37	35	33	31	29	27	25	23	21

EXPERIMENT



Question to be answered. How does moving air affect the rate of evaporation?

What you need. Two pieces of cloth each the same size (about one square yard) and the same material; two clothes hangers; two yard sticks; two objects that can be used as weights; two ringstands with clamps.

What to do. Soak each cloth in water, wring out until no more water can be squeezed out, and hang over one of the clothes hangers. Hook each clothes hanger on the end of one of the yard sticks. Suspend the yard stick in the center and tie weights on the ends opposite from the hangers. Arrange each weight until it balances the hanger, and record the time with both the minute and second hands of a watch. Put one of the set-ups in a part of the room where there is no air blowing over it. Fan the other gently, making sure that the force of the air does not upset the balance. Observe the two set-ups until each cloth has lost sufficient water to upset the balance. Record the time that it took for this to happen in each set-up. Repeat the above several times, and make an accurate record of the time for each.

Your answer. What is the one difference between the two set-ups? Which is your control? Why were you instructed to repeat the experiment several times? Did you get the same results each time? What was the average time that it took to unbalance each set-up? Why did both set-ups become unbalanced after a while? In one sentence, answer the above experimental question.

Some basic assumptions. 1. Timing was accurate in all observations.

2. In all instances less air was moving over the control set-up than the experimental one.

3. Only the loss of water accounted for the change in balance.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The surface of air separating two air masses is known as (a) a front; (b) a cyclonic storm; (c) an isobar; (d) a low.
2. The center of a cyclonic storm in which the air is ascending is called a (a) high; (b) low; (c) cold front; (d) warm front.
3. A barometer is used to measure (a) temperature; (b) humidity; (c) rainfall; (d) pressure.
4. When the water vapor which the air actually contains is compared with the total amount it could hold at any one temperature, the result is known as (a) absolute humidity; (b) barometric pressure; (c) relative humidity; (d) an isobar.
5. Weather proverbs and signs should be (a) believed because they have stood the test of time; (b) dismissed from mind because none of them have any sound basis; (c) relied upon in preference to forecasts by the weather bureau; (d) believed only if shown to have a sound basis.

PROBLEM 2. How do we adjust to weather?

IMPORTANCE OF WEATHER

Attempts to control the weather. Many attempts have been made to control the weather. Early man believed that the weather was controlled by certain gods to whom he could appeal whenever he desired a change in the weather. Some people still try to change the weather by practicing certain ceremonials.

As you will recall from Chapter 15, a great deal has been learned about the way atmospheric conditions determine the kind of weather we will have. Attempts have been made to change the atmospheric conditions within a cloud in order to form rain. In some of these attempts, particles of dry ice were distributed through the cloud from an airplane, thus causing the water vapor in the cloud to condense. In others, a smoke of silver iodide has been used to supply the tiny particles upon which water vapor can condense. Some claim to have been successful in using these methods. But many meteorologists consider these attempts as experimental and the results not conclusive. The atmosphere is so extensive that man has not yet learned to change it on a large enough scale to make it possible for him to actually control the weather.

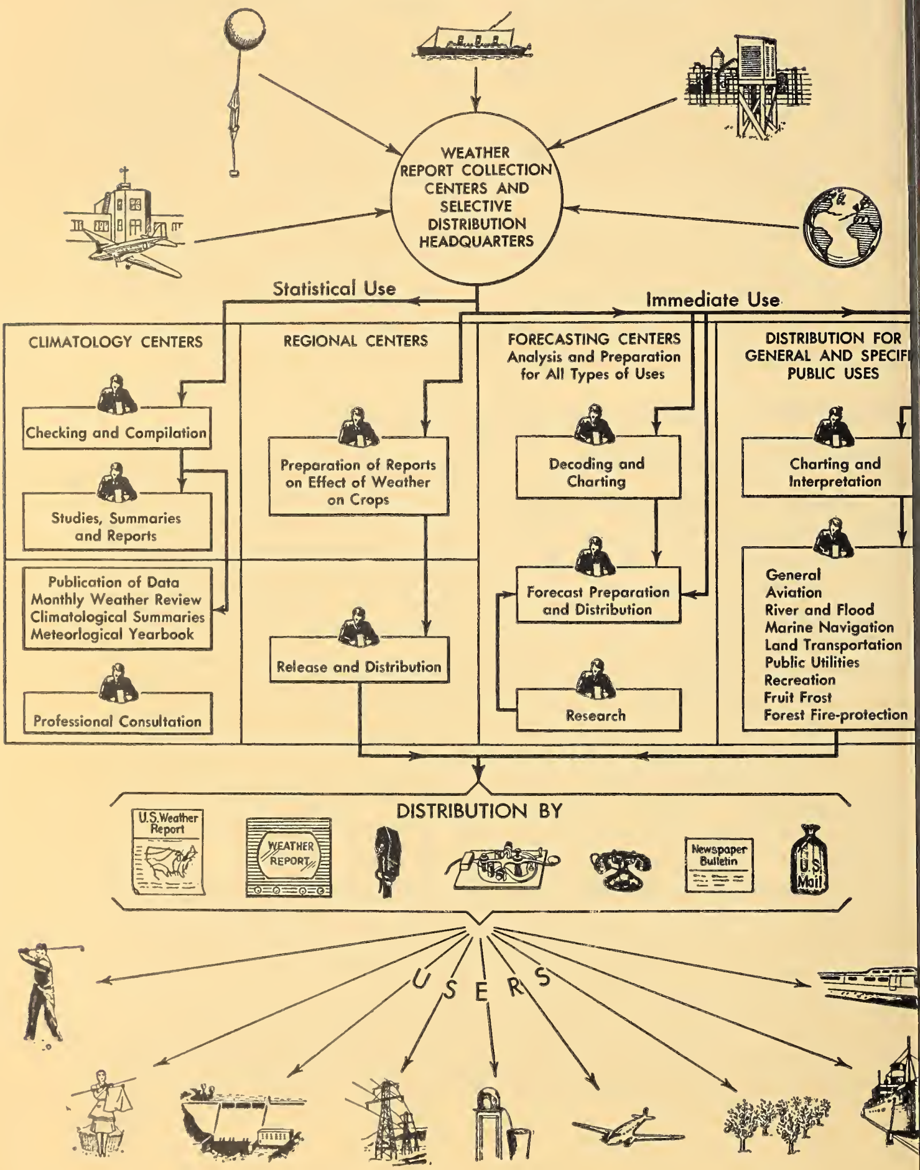
Since no practical way of controlling the weather has been discovered, people must adjust their activities to each day's weather. This they can generally do satisfactorily if they know what tomorrow's weather will be.

The United States Weather Bureau. Today's weather in Chicago or Cleveland may be tomorrow's weather in New York or Philadelphia. You have seen in Chapter 15 how accurate forecasts of tomorrow's weather for one part of the country are dependent upon a knowledge of today's weather condi-

HOW THE WEATHER BUREAU OPERATES

SOURCES OF WEATHER REPORTS

Airports; Upper Air Soundings; Ships at Sea;
Special Observers; International Interchanges



tions in other parts of the country. The tremendous task of collecting weather information from all over the country and preparing weather forecasts for different sections is now carried on by the United States Weather Bureau.

The Army, Navy, and Air Force as well as certain commercial airlines, which maintain weather-forecasting services for their own use, co-operate closely with the United States Weather Bureau in collecting and reporting weather information which is used for many purposes (see chart on the facing page).

Careful consideration of weather forecasts. Regardless of our occupations, we are all interested in the daily weather. This is true especially if we are planning outdoor activities dependent upon clear weather. Because of this interest in weather, newspapers and radio and TV stations issue the daily forecasts; in some cities, one can even dial a certain telephone number and receive the weather forecast automatically. The weather forecast appearing in your daily paper generally applies to a rather large area, such as a section of a state. Such a regional forecast may not always turn out to be accurate for the place where you live. When you read a weather forecast, always find out to what region it applies.

Newspapers frequently summarize the original forecast in one sentence or even one word. This may modify the meaning of the original forecast. If you are really concerned about tomorrow's weather, you should always consider the complete forecast very carefully. No single word or phrase can be used to forecast completely anything as complex as weather.

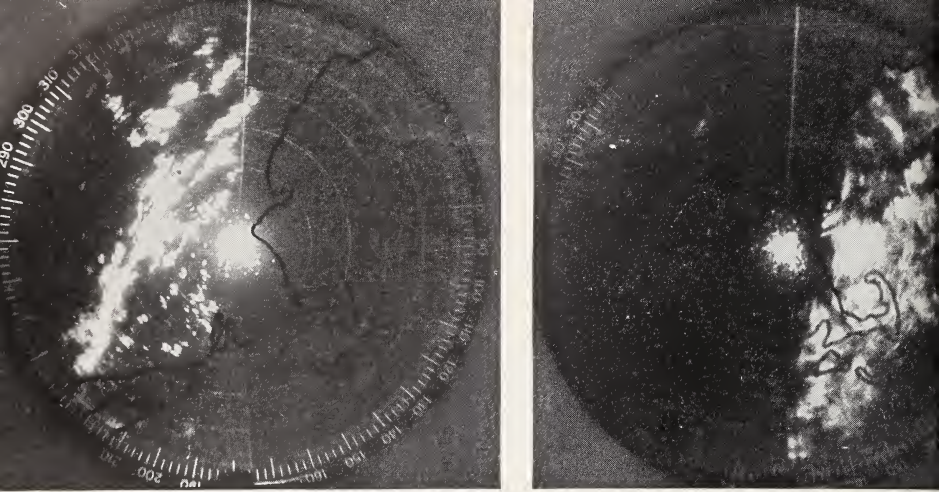
PROTECTION AGAINST WEATHER

Protection from wind. If adequate precautions are not taken, winds may cause destruction of property and loss of life. In sections of the United States where tornadoes frequently occur, people have built storm cellars where they can be safe from the destructive winds. Whenever possible, sirens, whistles, and radio broadcasts are used to warn the people of an approaching tornado.

In certain sections of the United States, tropical cyclones or hurricanes, which cover larger areas than tornadoes, occur frequently. During the hurricane season, July to October, the United States Weather Bureau maintains a hurricane warning service along the Atlantic, Pacific, and Gulf coasts. Observation points are established so that a hurricane can be located and the direction and speed of its movement determined. Airplanes and radar are used in observing the forward movement of the hurricane. Inhabitants of places where it is evident the hurricane will strike can be warned one or two days in advance so that they can make preparations to protect themselves and their property.

In hurricane country, the buildings are constructed to withstand the strong winds. During the hurricane season, windows and doors are equipped with heavy shutters or covers. Valuable trees with shallow root systems are braced. Oftentimes hurricanes cause high ocean waves that destroy life and property not adequately protected.

In the plains country, where there are few natural obstructions to strong winds and drifting snow, windbreaks of various kinds have been built. Often rows of trees are planted to break the



M. I. T. Weather Radar Research

At left the radar screen (with Boston its center) has picked up an approaching hurricane at 7:00 P.M. The screen at right at 3:00 A.M. the following morning shows that the hurricane has passed the center and is headed out to sea.

tremendous force of the wind, thus keeping valuable soil from being blown away and protecting livestock from cold winds. Snow fences are often used to break the force of snow-laden wind and prevent snowdrifts on highways and railways.

Protection from excessive precipitation. Storm sewers are constructed in most cities to prevent rain and melting snow from flooding the city and damaging property. Large underground pipes carry the water to a river, lake, or ocean. In some places where snowfall is heavy during the winter, snowsheds are constructed over parts of highways or railroads where it would be most difficult to remove snowdrifts. The roofs of houses in regions of heavy snowfall are steeply pitched to prevent the snow from piling up and causing the roof to collapse.

During periods of heavy rainfall, rivers often break through their banks and flood lowlands, causing great losses of life and property. It is estimated that floods in the United States result in an average annual property loss of $100,000,000. Several methods are used to prevent disastrous floods. In some places, *levees* or high banks are constructed to hold floodwaters in the channel of the river. In a few places, large reservoirs are built to collect rain water that would otherwise cause floods.

A river-and-flood forecasting service is operated by the United States Weather Bureau. There are 85 river-forecasting districts which include all of the principal rivers and tributaries in the United States. The headquarters office in each district collects information about rainfall and amount of water flowing in rivers and tributaries throughout the district. From these data it is possible to forecast floods well in advance of the time they will actually occur. Warnings are issued so that people and livestock can be evacuated from areas that will be flooded. It has been estimated that the flood-forecasting service saves the American people an average of $15,000,000 a year.

Protection from lightning. Lightning must be regarded as a destructive force. It kills about 400 people every year in the United States. There are several precautions which one should take to avoid being struck by lightning: Avoid open spaces such as fields, golf courses, and beaches when a thunderstorm is threatening. Although it is much safer inside a house or large building, it is wise to stay out of the attic and away from chimneys and walls. The safest place in the house is near the center of a room. It is not safe to ride bicycles, horses, and exposed machines such as tractors, although a person is safe inside a closed automobile provided it has an all-steel body. It is dangerous to stand near tall objects like trees or flag poles or near wire fences and other kinds of metal objects which are conductors of electricity.

Lightning also damages or destroys buildings, forests, oil-storage tanks, and power-transmission lines. It is estimated that lightning each year destroys farm buildings valued at $12,000,000. Much of this loss could be prevented if lightning rods were used on buildings and other tall objects. When a lightning rod is properly installed, it may protect the building in two ways. It may prevent the electrical charge between an object and a cloud from becoming great enough to cause a flash of lightning to jump between them; or if a lightning flash should occur, the rod may receive the force of it so that it is carried off without damaging the building.

The United States Weather Bureau maintains a fire-weather organization in ten Weather Bureau offices. The meteorologists in these ten centers specialize in forecasting humidity, wind, and thunderstorm conditions in forested and mountain areas. They issue daily forecasts covering detailed weather conditions to be expected in each forest-ranger district. This gives the authorities a chance to move fire-fighters and fire-fighting equipment near areas where forest fires are most likely to be started by lightning.

Protection from extreme temperatures. There are many ways in which we protect ourselves from hot and cold weather. Our houses provide protection from storms and extreme cold or heat. We have learned how different types of clothing may be used to protect our bodies from extreme temperatures. Automobiles, buses, airplanes, and railway coaches are being equipped today so that passengers can ride in air-conditioned comfort.

Citrus fruits are grown in parts of the United States where the year-round temperatures are generally favorable for plant growth. But occasionally during the winter months in such places, cold air may move in and cause the temperature to drop below freezing. Before growers knew how to protect their orchards from these occasional cold periods, the annual citrus-fruit production in the United States was far below what it is today. Now during the winter months when freezing temperatures may occur, growers place oil burners throughout their orchards to protect the fruit from the cold.

Truck farmers, cranberry growers, and producers of other kinds of crops that could be damaged by unseasonal frosts use various methods to protect

United Air Lines

A meteorologist gives pilots weather information before they take off. A knowledge of the weather conditions an airplane pilot is likely to encounter helps insure a safe flight.

their crop. In some instances they also may use smudges. Truck farmers often cover young, tender plants to protect them from freezing. Cranberry growers flood the cranberry bogs with water whenever there is danger of freezing temperatures in the fall before the berries are picked. Water loses its heat so slowly that it will prevent freezing during short periods of low temperature.

The United States Weather Bureau maintains a frost-warning service in seven states where winter and spring fruits and vegetables are produced in large quantities. Meteorologists keep a constant watch for the approach of cold air and freezing temperatures. Warnings are issued to growers well in advance of the frost so that they may take the necessary steps to protect their crops from freezing.

There are many other ways in which man attempts to adjust his activities to temperature changes. Railroads, trucking lines, and river and ocean freighters provide special protection to shipments of products that might be damaged by either hot or cold weather. During hot weather, refrigerator freight cars are used; during cold weather freight cars are heated. In large cities whenever cold snowy weather is forecast, many preparations are made. Operators of heating plants obtain additional supplies of fuel and get their heating equipment in shape to supply more heat. Natural gas companies and coal and fuel-oil dealers get ready to take care of increased demands. Water pipes exposed to outdoor air temperatures are drained. Street maintenance crews get their equipment ready to remove snow and ice from the streets. Arrangements are made to discontinue certain kinds of outdoor construction, such as concrete work, during cold weather. Merchants display clothing for cold-weather wear.

Protecting aviation from weather changes. Almost no other activity of man is more dependent upon weather than aviation, for atmospheric changes have a direct effect upon flying. In cooperation with the United States Weather Bureau, both military and commercial airports keep a complete record of weather conditions. The records include visibility, wind conditions, icing, rough air, extent and height of clouds, temperatures, and storms within flying distance of the airport. Such weather records are carefully checked by officials responsible for releasing airplanes for flight. All aircraft are grounded whenever weather or flying conditions are not safe. Not only is a pilot given a complete report of the weather he will encounter before he takes off; but also during flight, he maintains radio contact with airports along the route and is informed of weather changes that might lie ahead. He may also report atmospheric conditions at the altitude at which he is flying. Radar instruments also are used to make flying safer during bad weather.

SUMMARY

The amount of atmosphere covering the earth is so great that man has not been able to control successfully the changes which occur in it. He has therefore had to accept weather changes as they occur and modify his activities so that changes in the weather will cause him least inconvenience. Through the United States Weather Bureau, forecasts of weather that might result in loss of life and property are periodically released to persons who would be affected. Man adjusts to weather changes by attempting to protect himself and his property from extreme temperatures, winds, and too much precipitation.

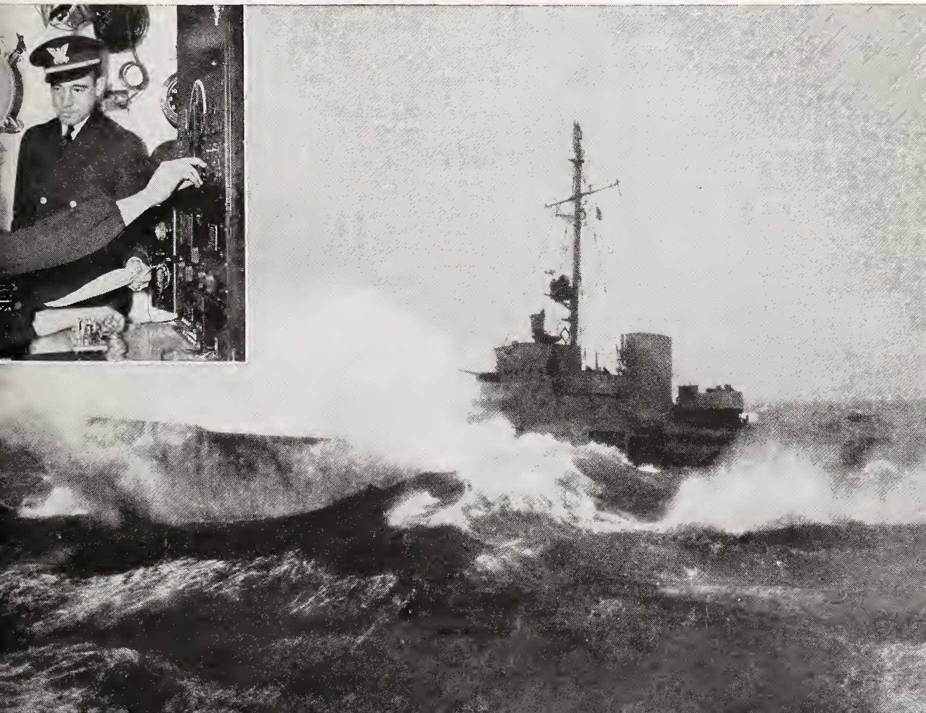
TEST YOURSELF

Write the letter of the best answer to each of the following questions in the proper place on your answer sheet.

1. The most scientific method of attempting to control weather is (a) to practice ceremonials; (b) to scatter dry ice or smoke through clouds; (c) to make sacrifices to

Weather ships go about their observations sometimes in heavy seas. The reports are sent by radio operators to the Weather Bureau in Washington, where they are used to prepare weather maps and forecasts.

U. S. W. B.—U. S. Coast Guard



rain gods; (d) to explode a stick of dynamite.

2. The safest place to be during a thunderstorm is (a) on a bicycle; (b) on a tractor in the field; (c) inside a car with a steel body; (d) on a horse.
3. A device intended primarily as a protection against excessive precipitation is (a) an oil burner; (b) a levee; (c) an air-conditioning unit; (d) a storm cellar under a house.
4. The estimated amount of money saved the American people each year by flood forecasting is (a) $1,500; (b) $15,000; (c) $15,000,000; (d) $1,500,000.
5. Trees are most often planted as windbreaks (a) in large cities; (b) near forests; (c) along rivers; (d) in open plains country.
6. The method used by cranberry growers in protecting their crops from low temperatures is (a) flooding; (b) covering with straw; (c) oil burners; (d) windbreaks.

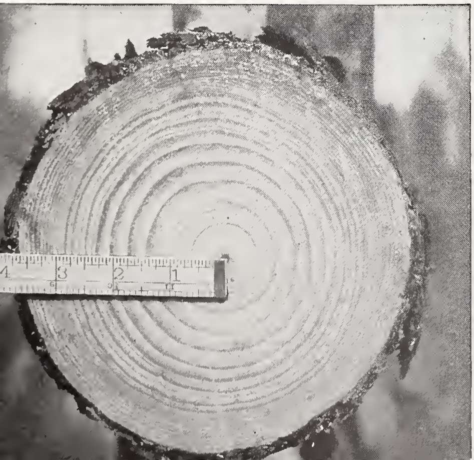
PROBLEM 3. How do we adjust to climate?

KNOWLEDGE OF CLIMATE

Climate—a history of weather. Only within the last three hundred years has any systematic attempt been made to keep accurate historical records of weather. For earlier records of weather, we must depend upon historical accounts of other events. Some attempts have been made to determine what past weather conditions were like by using the *if—then* method. One clue is the size of the annual tree rings, shown in the picture below. By studying such tree rings, scientists have been able to describe the general weather conditions which were present during the life of the tree. An accurate history of weather, however, can be obtained only by keeping a record of temperatures, precipitation, and the other conditions making up weather.

This pine tree was 22 years old when it was cut. The width of each of its 22 annual rings shows how much it grew each of those years and provides clues to growing conditions, and thus the kind of weather during that year.

U. S. Forest Service



The Climatological Service of the United States Weather Bureau keeps a weather history for each of the states, as well as for Alaska, Hawaii, and Puerto Rico. Each climatological center collects records of weather observations from the numerous stations in its state. Periodic reports covering the weather history of each state are then published. The Climatological Service exchanges weather reports with other countries so that records of foreign climates are also maintained in the United States.

Interest in climate. We may be interested in the climate of a particular place for various reasons. If we find it necessary to move to another section of the country, one of our first questions is, "What kind of climate does it have?" Many of us prefer to live in a place where the climate is neither too hot nor too cold, neither extremely wet nor extremely dry. The farmer is concerned because the kinds of crops he can raise and the amounts he can produce are largely dependent upon climate. The way he will carry on his farming activities is also influenced by climate. Commercial airlines may want to know about the climate because it determines the number of good flying days in a year. Construction engineers are always concerned not only about the kind of weather conditions their roads and buildings will have to withstand, but also about working conditions while they are building.

Agricultural practices and climate. Agricultural or farming practices must be adapted to climatic conditions. The kind of crops that a farmer can raise is determined by the length of the growing season, the daily temperatures, and the amount of rainfall. In sections of the United States where the summers are long, hot, and wet, crops such as cotton are grown. In other regions where the growing season is shorter and there is less rainfall, crops such as corn and wheat will grow well. Plant scientists have discovered or developed crop plants that can grow well in most of the climatic conditions found here.

Irrigation. In some of the drier sections of the United States, farmers can increase the variety of their crops by supplying them with extra amounts of water. Such a practice, called *irrigation,* is shown on page 300. Water may be obtained from rivers or deep wells for irrigation. Although irrigation is expensive and requires considerable labor, large crop yields make it a profitable agricultural practice in many places.

Dry farming. Where irrigation water cannot be obtained, farmers in dry climates conserve the small amount of rainfall by using various methods generally called *dry farming.* One common practice in dry farming is to plant fields only once every two years. In this way much of the moisture is saved during one summer for use the following summer in producing a crop.

Agricultural pests. Cold winters with freezing temperatures limit the number of insect pests that can survive from one summer to the next. In climates with mild winters, insects may survive in large numbers from one growing season to the next. Although farmers can grow many varieties of crops in wet climates with long growing seasons, the problem of controlling insect pests and plant diseases like grain rusts which thrive in such conditions, requires much labor.

Livestock raising. There are large areas of land in the western part of the United States where rainfall is so limited that farming is not practical. Ways have been found to use these lands to advantage. Some of the land produces short grasses that are used to feed cattle or sheep. These grass lands are called *ranges.*

Lumbering. Lumbering is another important industry dependent upon climate. The large forest areas of the United States are located in regions that have the greatest rainfall. Many of our large forests grow on land that is

Soil Conservation Service

This farmer is adjusting his methods to a dry climate. He is irrigating a crop of potatoes by running the water between rows and allowing it to soak into the soil.

not suitable for other kinds of crops. In such areas where forests have been removed, trees are planted in order to make the best use of the climatic resources.

Aviation. Before selecting a site for the Air Academy, the Air Force made careful studies of suggested locations to determine whether their climates were suitable for year-round flying. Colorado Springs, Colorado, was finally selected because, among other things, it has many good flying days each year.

Highways and railways. Before highways or railways are built through a region, the climate is carefully studied. The annual amount of precipitation and the time of the year when most rain and snow fall must be considered in deciding how the roadbed should be constructed. The lowest and highest temperatures are important considerations in determining the most suitable construction materials to be used.

Health. Although at one time it was believed that climate was a direct cause of certain diseases, this idea is no longer accepted. People who have studied the effects of atmospheric conditions upon health have shown that climate influences man's health and energy in two ways: (1) by its effect on the distribution of disease-producing organisms, and (2) by the physical requirements it places upon the human body.

Some diseases are more common in one climate than another. Certain diseases which are transmitted from person to person by insects are common in warm humid climates where these disease-carrying insects thrive. The mosquito which transmits malaria and the yellow-fever mosquito, for example, are both insects of warm climates. Neither of these diseases is common in colder climates. Hookworm disease is found only in warmer climates. On the other hand, the germ causing scarlet fever does very well in cold climates although it is unknown in the tropics.

As we learned in Chapter 13, heat is produced in the body by physical activity. Furthermore, the body is cooled by losing heat to the surrounding air. Therefore it is possible for people to be more active in cooler climates without overheating the body. For these reasons, people in temperate and colder climates appear to be more energetic than people in tropical climates. In climates where the relative humidity is generally below 20 per cent, the air dries and irritates delicate parts of the body with which it comes in contact. As a result, the breathing passages may be more easily infected with the germs causing colds and other respiratory diseases. On the other hand, patients suffering with tuberculosis are often sent for treatment to places where the humidity is low and there are many sunny days.

SUMMARY

In order to live most efficiently in any climate, man must adjust his activities to the types of weather characteristic of that climate. The way man uses the soil, the kinds of businesses in which he engages, and his health are all influenced by climate.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. An accurate history of weather (a) has been kept for many centuries; (b) can be obtained by studying tree rings; (c) has been kept within the last three hundred years; (d) is impossible to keep because it changes so often.
2. Farming is sometimes adjusted to dry climates by (a) irrigation; (b) listening to weather forecasts; (c) use of fertilizer; (d) using a radiosonde.
3. Climate is of least importance in (a) farming; (b) constructing highways; (c) mining metals; (d) lumbering.
4. Climate influences man's health by (a) causing certain disease; (b) determining the health value of food; (c) affecting the distribution of disease-producing organisms; (d) affecting the cleanliness of living conditions.
5. Commercial airlines are concerned about the climate of places where they may locate airfields because the climate often determines (a) the number of good flying days in a year; (b) the need for air travel; (c) the type of airplane to be used; (d) the amount of gasoline needed.

CHAPTER ACTIVITIES

REVIEW WEATHER AND CLIMATE

1. Below are several facts about weather forecasting. Following these facts are three generalizations. On your answer sheet, write the letter of the generalization which best includes all the facts stated. **Do not write in your textbook.**

FACTS

1. Air masses are made up of either cold or warm air.

2. Air masses move slowly across the country.

3. A low moves as a wave along the front between masses of cold and warm air.

4. Lows are often accompanied by changes in weather.

5. Highs are often accompanied by fair weather.

6. The location, nature, and direction of air movements are determined by studying measurements made at a number of places.

7. Using measurements of atmospheric conditions, the weather forecaster predicts with some accuracy the weather from day to day.

GENERALIZATIONS

a. The movement of air masses determines the weather changes that will take place in different places throughout the country.

b. The study of air movements and changing characteristics makes it possible to predict weather a day in advance with considerable accuracy.

c. Since weather predictions are based upon careful measurements they are always accurate.

2. Below are several facts about man's adjustment to climate. Following these facts are three generalizations. On your answer sheet, write the letter of the generalization which best includes all the facts stated.

FACTS

1. Both dry farming and irrigation are methods of producing better crops in dry climates.

2. Grasslands in dry climates are used to feed cattle and sheep.

3. Lumbering is limited to climates where trees grow readily.

4. Although many crops can be grown in wet climates with long growing seasons, the problem of controlling insect pests and plant diseases is difficult and its solution is expensive.

5. Man must protect himself against diseases that flourish in the kind of climate in which he lives.

GENERALIZATIONS

a. Climate has an important bearing upon farming and forestry because of the kind of vegetation that can grow in different climates.

b. Man controls climate by adjusting his activities to it.

c. What man does to protect his health and make a living is affected by the climate in which he lives.

INTERPRET A TABLE

On page 303 is a table showing the average monthly temperature in various North American cities. Listed below are a number of statements. On your answer sheet, mark each statement as follows: **T,** if the table contains enough information to make the statement *true;* **X,** if the table does not contain enough information for you to make a decision about the statement; and **F,** if the table contains enough information to make the statement *false.*

1. In September the average temperature is lower in Vancouver than in any other place listed on the table.

AVERAGE MONTHLY TEMPERATURE IN 1953

	MAY	JUNE	JULY	AUG.	SEPT.
1. Boston, Massachusetts	58.4	70.5	73.2	72.0	66.3
2. Chicago, Illinois	61.0	73.6	76.4	75.8	67.6
3. Honolulu, Hawaii	76.8	77.7	78.3	79.4	78.8
4. Los Angeles, California	63.9	66.8	74.9	70.7	70.2
5. Mexico City, Mexico	67.3	64.9	62.2	61.5	58.6
6. New Orleans, Louisiana	79.1	84.5	83.3	82.9	80.9
7. New York, New York	62.1	71.6	76.0	75.2	69.1
8. Philadelphia, Pennsylvania	65.3	73.2	78.8	76.9	70.1
9. Vaucouver, British Columbia	55.0	57.2	64.0	63.0	56.0
10. Washington, D.C.	65.2	74.0	77.0	74.0	68.0

2. The average temperature in Boston during July, 1953, was 73.2.

3. The average temperature is usually higher in May than in September in Washington.

4. If you were going to Vancouver for a vacation, you would expect it to be warmer in July and August than in the other summer months.

5. Since there is very little difference between the average summer temperatures in New York and Chicago, when it is hot in New York it is hot in Chicago.

6. In these ten places, it is hotter in July than in any other month.

7. Mexico City gets most of its hot weather in the wintertime.

8. It is never cold in Honolulu and New Orleans during July.

UNIT ACTIVITIES

APPLY YOUR KNOWLEDGE

Below are listed several suggested ways which might be used to forecast weather. On your answer sheet, write a **U** if you consider the suggestion to be *unreliable;* a **P** if you consider it to be *partly reliable;* and an **M** if you consider it to be *most reliable.*

1. Study the activity of squirrels in the fall when they bury nuts.

2. Note the changes in a barometer several times during the day.

3. Read a barometer which has the different kinds of weather ranging from *stormy* to *fair* printed on its face.

4. Observe the position of the "horns" of the moon.

5. Observe the length of fur on animals in the fall.

6. Study atmosphere measurements obtained from a number of different places.

7. Observe the width of the bands on Woolly Bear caterpillars.

BUILD WEATHER INSTRUMENTS

1. A simple mercury barometer
2. A weather vane
3. A sling psychrometer
4. A rain gauge
5. A cup anemometer
6. A hair hygrometer

MAKE VISITS

1. A weather bureau station to see how weather forecasts are made

2. An airport to see how weather forecasts are used in flying

CONDUCT INVESTIGATIONS

1. Collect a number of weather signs from people in your community. Find out which ones have some scientific basis.

2. Record the temperature at the same time each day for a week. Compare your results with those of your classmates. Account for any differences that may occur.

3. Keep a record of the weather for a month, and compare the actual weather conditions with those predicted by the weather bureau for your area. Do they agree?

4. Keep a record of the weather for a month and compare the actual weather conditions with those predicted in an almanac. How well do they agree?

5. Make a survey in your community to determine what businesses use daily weather forecasts.

REPORT ON WEATHER AND CLIMATE

1. The radiosonde and its use in weather forecasting
2. The use of radar in weather forecasting and flying in bad weather
3. Man-made weather for testing industrial products
4. Rain-making through the ages
5. Fog-dispelling methods
6. Exploring high altitudes to learn about the weather
7. Climate and health
8. The ice ages
9. Numerical weather prediction

READ ABOUT WEATHER AND CLIMATE

Bell, Thelma Harrington. *Snow.* New York: The Viking Press, Inc., 1954.

The author explains the mechanics of a snowfall, the help and the harm snow does, how an igloo keeps its tenants warm against temperatures of 50 below zero, the work of snow surveyors and many other fascinating things.

Burke, Jacqueline, and Wilson, Vivian. *Watch Out for the Weather.* The Viking Press, 1951.

A most interesting account of how our many activities, including our health and dispositions, are affected by the weather, and how we can do something about it.

Fisher, Robert Moore. *How About the Weather?* New York, Harper & Brothers, 1951.

A not too difficult treatment of weather and the problems of weather forecasting. A good deal of information on how to interpret weather maps is included.

Gaer, Joseph. *Everybody's Weather.* Philadelphia: J. B. Lippincott Co., 1949.

The effects of weather upon people of different occupations. Will help you learn how to forecast weather ways.

Schneider, Herman. *Everyday Weather and How It Works.* New York: Whittlesey House, 1951.

Clear and interesting explanation of weather with detailed instructions on how to make a home weather-forecasting station.

Spilhaus, Athelstan Frederick. *Weathercraft.* New York: The Viking Press, 1951.

Gives instructions on how to assemble and operate a home weather station. Most of the materials used are available around the home or can be purchased in the "dime" store.

FPG

Good health makes it possible for young people to enjoy life. An understanding of the body and how to care for it will help you keep healthy.

unit 8—HEALTH

WHEN we were babies our parents looked out for our health. We were fed the kinds of food the doctor considered necessary to build strong, healthy bodies. Our mothers took special care to keep us clean. We were given “shots” to protect us from a number of childhood diseases. There was a proper balance between rest and play. As we grew from babyhood, our parents continued to supervise our eating, sleeping, bathing, and the like. But after a while, our parents became less directly involved and we were supposed to take over. Most young people of your age have been given a good deal of responsibility for the care of your own bodies. To a certain extent you select the food you eat—at least those between-meal snacks. You have greater personal control over the amount of rest you get. You decide pretty much how you will dress in different kinds of weather. More and more, from now on, you will be on your own to make decisions regarding the care of your body. How will you do?

Your body is one of your most precious possessions. It is certainly one of your most complicated possessions. If you are going to take proper care of your body, there are a number of things that you should know about it.

Although there are many things that scientists do not know about our complicated bodies, it would be impossible in one book to tell you all that they do know. Nor would you be able to understand all of it. This unit has been written to help you understand better the way your body operates and how you can help it operate more efficiently. A study of this unit will help you understand the causes of some diseases, how your body protects itself from them, and how you can aid it. Finally, you will learn about the effects of alcohol, tobacco, and narcotics on the body. An understanding of this unit should help you to keep the healthy body which is rightfully yours.

National Dairy Council

Our bodies use food to obtain both the energy needed to carry on our many activities and the materials necessary for growth and repair.

chapter 17 THE HUMAN BODY

HAVE you ever wondered how your body is able to carry on so many different kinds of activities? It moves, carries loads, talks, reads, thinks, and does many other things. Energy is needed for these activities. Because the body uses food as fuel to obtain the energy, it has sometimes been called a machine. But the body is more complicated than any machine man has ever built. The body is never turned off, but operates continuously throughout life. No engineer or pilot is needed to run it. The body itself regulates the speed at which it operates. When damaged, it repairs itself. This chapter should help you understand how your body carries on some of its important activities.

PROBLEM 1. How does the body operate?

THE MAKE-UP OF THE BODY

A body of cells. Whenever we think of our bodies, we generally think of one individual made up of head, neck, trunk, arms, and legs. But our bodies are actually made up of millions of smaller parts. Each of these little parts is called a *cell,* and is so small that it has to be greatly magnified with a microscope before it can be seen. The body is made up of a number of different kinds of cells, such as skin cells, muscle cells, nerve cells, and blood cells, as shown below.

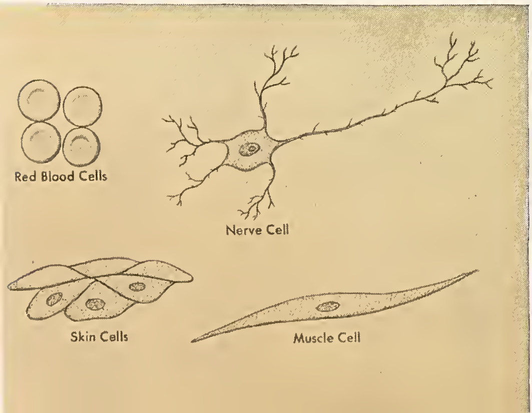
A group of cells doing the same kind of work is called a *tissue*. Skin, muscle, and bones are examples of tissues. *Organs* of the body, such as heart, lungs, and stomach, are made up of several different kinds of tissue. As you shall see later in this problem, the different organs of the body work together to perform such functions as the digestion of food.

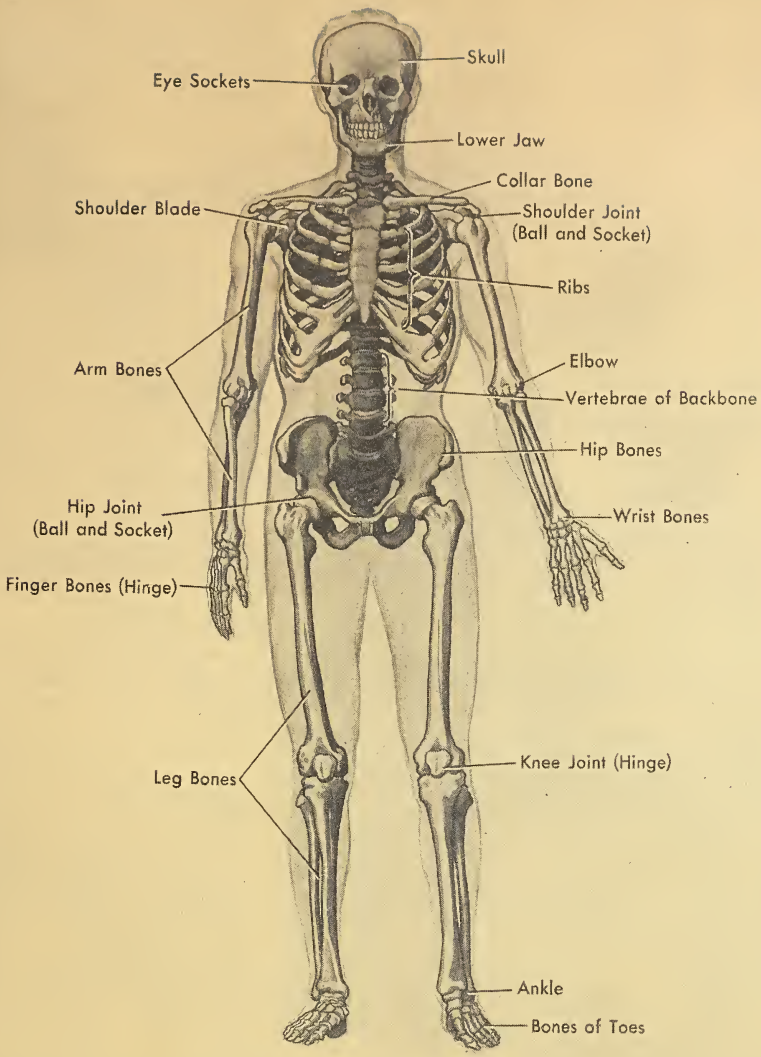
Protoplasm, the life of the body. Each living cell of the body is made up of a substance called *protoplasm,* which is a jelly-like material something like the white of a raw egg. Each cell is surrounded by a denser layer of protoplasm called the cell *membrane,* which separates the protoplasm of each cell from that of every other cell. Cell membranes also make it possible for cells to exist in different shapes. Protoplasm within cells carries on all the activities of living things. It takes in or absorbs food and obtains energy from it. With this energy it moves, stretches, or shrinks itself, or carries messages over the body. Protoplasm also uses food to make more protoplasm so that cells can grow and new cells can be formed. The new cells thus formed may be used in making the body larger or in repairing worn-out parts. Everything that happens in the body is the result of activities carried on in the protoplasm within the cells of our body.

Bones, the framework for body activities. Bones in the body form a framework which makes it possible for the body to do its work most effectively. The hard part of bones is made up primarily of calcium and phosphorus, compounds produced by the protoplasm of bone cells from the food we eat. The *skeleton,* as the bony framework of the body is called, is made up of more than 200 different bones. Some of these support and protect important parts of the body; others make it possible to move about and grasp things.

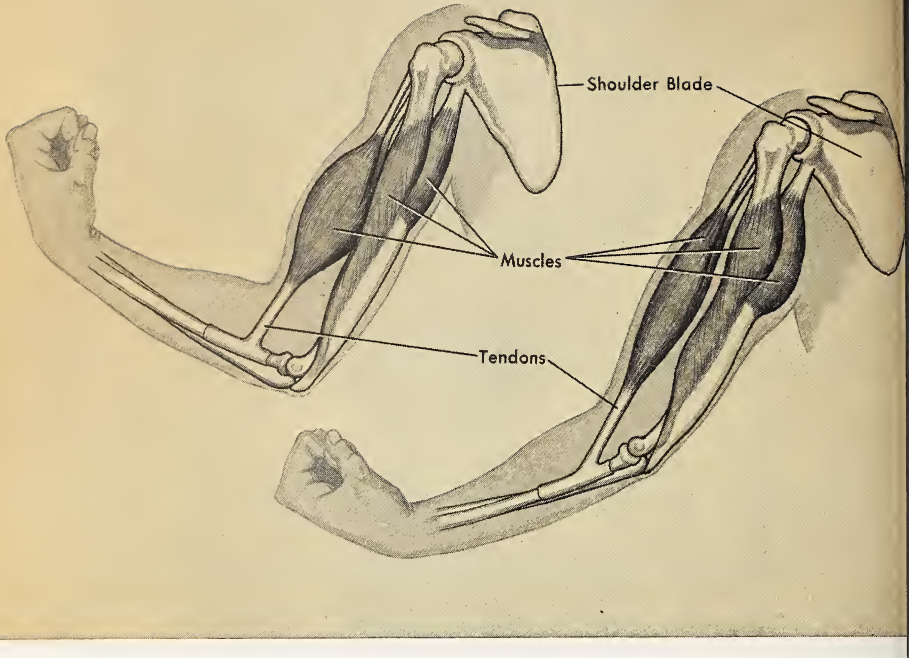
You can move your arms, fingers, legs, and toes because of connections between bones called *joints*. You will notice that your upper arms and legs

Each kind of cell in the body differs in appearance from other kinds of cells and has a special job to perform. Red blood cells carry oxygen; nerve cells carry messages; muscle cells move the body; and skin cells cover it.





Important bones and joints of the human skeleton. Bones of the head protect the brain and eyes, whereas the ribs protect other vital organs and help support the body as well. The backbone protects the spinal cord and provides support. Arm and leg bones not only support the body, but also make it possible for us to move.



To move the forearm upward, as shown at left, one set of muscles shortens and becomes thicker as it pulls the bones of the forearm upward, whereas the other set of muscles lengthens and becomes thinner as it releases the bones of the forearm so that they can be pulled upward. When the forearm is lowered, as shown at the right, the action of the muscles of the arm is reversed.

will move in any direction, but your elbows and knees only back and forth. This difference in movement depends on the type of joint. Upper arm and leg bones are attached to the rest of the skeleton by *ball-and-socket joints,* allowing movement in any direction; elbow and knee depend on *hinge joints* which permit only back and forth movement. Still another kind of joint, the *sliding joints* in lower arm and wrist, slides back and forth over each other. Bones are held together at the joints by tough tissue called *ligaments.*

Muscles for action. Muscles are necessary not only to move the body about but also for other types of movement. Chewing food, swallowing food, and passing food through the stomach and intestines are all made possible by the action of muscles. Muscles make heart action and breathing possible. Eye movements in reading, a smile, and even a faint sigh depend upon muscles. Some muscles are thin, others thick and heavy.

All moving parts of the skeleton have muscles attached to them by *tendons*. These *skeletal muscles* control the movement of parts of the skeleton to which they are attached.

Muscles are able to move different parts of the body because they can lengthen and shorten easily. All muscular action takes place by this lengthening and shortening process (page 310).

THE DIGESTION OF FOOD

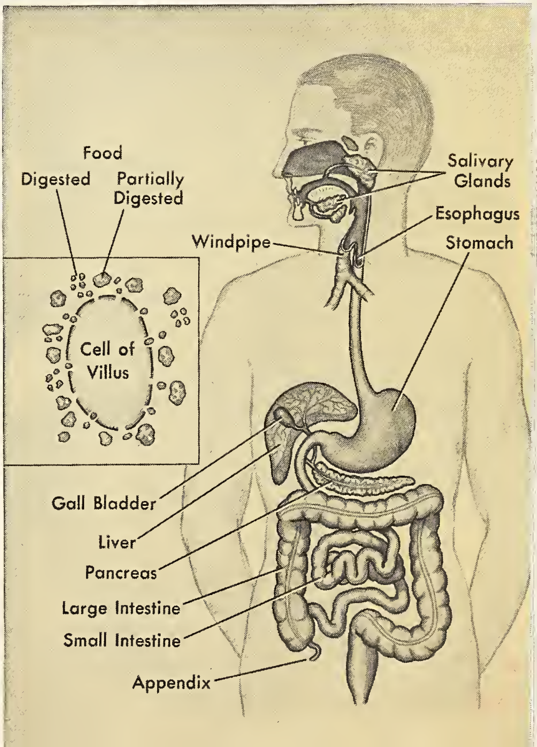
Food for energy and building materials. Whenever you walk, talk, play games, swim, work, or dance, your muscles use energy. Even when you are sitting quietly, lying down or sound asleep, or just thinking, your body is using energy. It takes energy to breathe and for your heart to beat. In fact, the body needs energy every moment throughout life. To supply this energy, our bodies use food. Food also supplies materials needed by the body to heal injuries such as cut fingers and broken bones, to grow hair and the outer layer of skin as it is worn away, and to produce more muscles and bones as an individual grows.

When we say that the body uses food, we actually mean that every living cell in the body uses food. Without food, cells of the body would soon die.

Digestion prepares food for use in cells. The bread, butter, jam, potatoes, carrots, meat, eggs, and other foods that you eat cannot be used directly by cells in the body. They have to be changed chemically before they can supply energy and materials for growth and repair. As you will recall from Chapter 3, substances such as foods are made up of molecules. Most of the foods we eat are composed of large complex molecules which cannot enter the cells and be used until they are changed into smaller, simpler ones. Whenever molecules are changed, it is said to be a chemical change. The chemical process whereby large complex molecules of food are changed into smaller, simpler molecules is called *digestion.*

Digestion in the mouth. In the mouth food is crushed into smaller pieces by the teeth. As the food is chewed, it is mixed with a digestive juice called *saliva,* produced by *salivary glands* (see drawing, below). *Glands* are special organs in the body producing chemical substances which aid in carrying on certain activities within the body. The saliva contains a chemical which changes some of the large molecules of starchy foods, such as bread and potatoes, into smaller sugar molecules. Thorough chewing reduces food to smaller particles and assists this chemical action of saliva.

As food passes through the digestive system, the large molecules of food are broken down into smaller ones. As shown in the inset, the digested food can then pass into the cells of the villi from which it enters the circulatory system of the body.



Digestion in the stomach. After the food is swallowed, it is carried through a tube, the *esophagus,* into the stomach, which can hold about a quart. There are three layers of muscles in the walls of the stomach. When food is in the stomach, the combined action of the different layers of muscles causes churning movements in the walls. By this movement, solid and liquid foods are mixed with the digestive juices in the stomach to form a heavy liquid. The digestive juices are produced by millions of small glands in the wall of the stomach. These juices contain some hydrochloric acid and other chemicals that start the digestion of another kind of food like lean meat and eggs, called *protein.* The work of breaking up the large protein molecules begins in the stomach but is not completed until the food passes into the small intestine. It may take from two to six hours before an entire meal is liquefied and emptied from the stomach into the small intestine.

Digestion in the small intestine. The *small intestine* (see page 311) is a tube about one inch in diameter and about 20 feet long. Muscles in the walls of the small intestine produce a wave-like movement that keeps the food passing through.

As the partially digested food from the stomach passes through the small intestine, three different kinds of juices are added to it. One is a digestive juice produced in the *pancreas,* a gland located near the stomach (see page 311). The second is produced by glands in the walls of the intestine. The third juice, called *bile,* aids the action of other juices. Bile is produced by the liver and emptied into the small intestine through a tube.

These three juices complete the digestion of food in the small intestine. The molecules of starch which were not digested in the mouth and the larger molecules of sugar are changed into a simple type of sugar. The breakdown of protein molecules is also completed in the small intestine. Fatty foods such as cream and butter are not acted upon until they reach the small intestine; but here they are digested and broken down into simpler molecules that can be used by cells. All digested foods are now ready to be carried to the cells of the body. But what happens to undigested foods?

Elimination of wastes from intestine. Many of the foods we eat contain materials which the human body cannot digest. Such materials are eliminated as wastes. They pass into the *large intestine.* Here no digestive juices are produced. Instead much of the water in the waste materials is absorbed by the walls of the large intestine. The water is then returned to the blood stream. The wastes are stored in the lower part of the large intestine until they are passed from the body as a bowel movement.

From small intestine to the blood. How do digested foods get to the cells of the body? The walls of the small intestine are lined with millions of very small finger-like projections, called *villi* (or *villus* when you refer to only one of them). The villi are so small that you cannot see them unless they are magnified under a microscope. Within each villus are two kinds of tiny tubes. One, the *lymph tube,* contains a colorless fluid called lymph; the other contains blood and is called a *capillary.*

Since digested starches, sugars, and proteins are dissolved in water, they can pass through the walls of the villi into the blood contained in the capillaries. Digested fats pass through the villi walls into the lymph, which is collected in larger tubes or vessels and later emptied into blood vessels.

THE CIRCULATORY SYSTEM

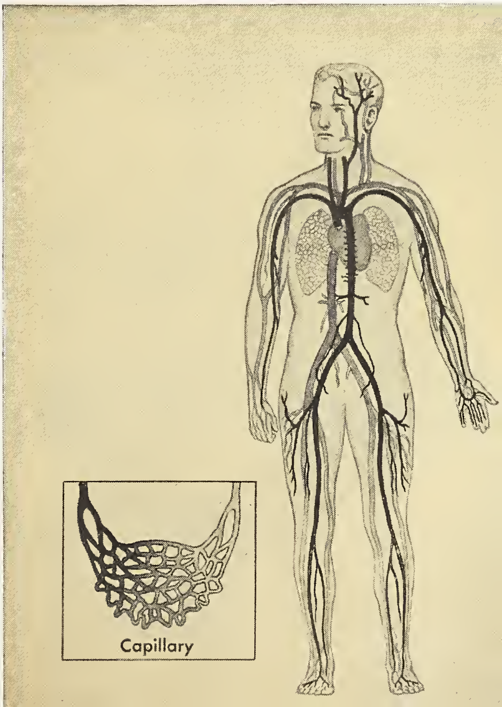
The blood in our bodies. Blood contains a number of different substances which make it possible for it to do many things. The liquid portion, called *plasma,* is mostly water, and makes up more than half of the blood. The blood also contains red blood cells, white blood cells, small disc-shaped bodies, and other substances.

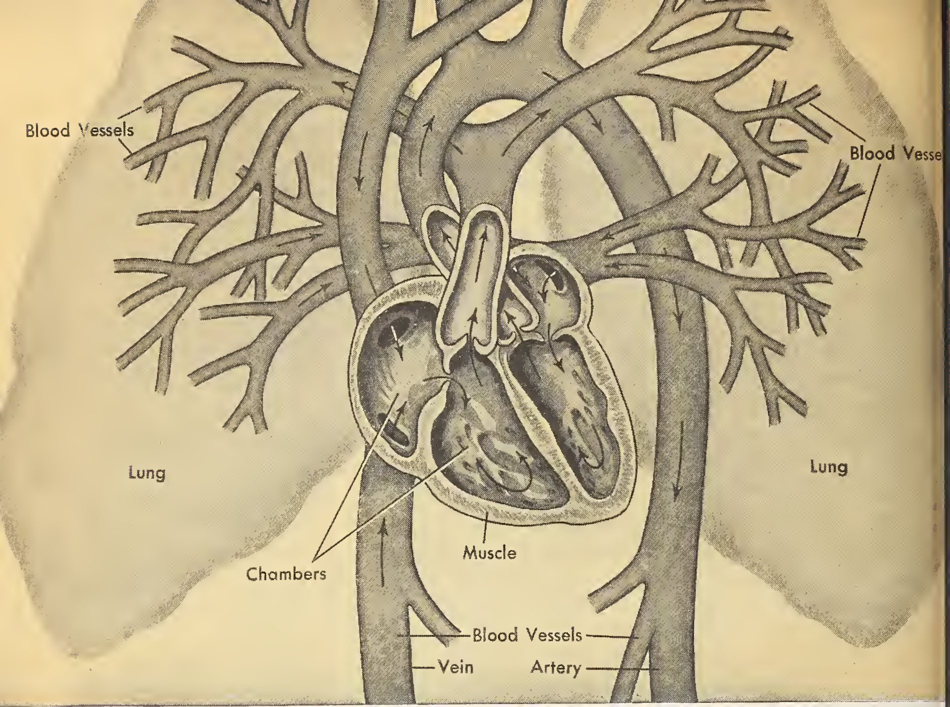
A medium-sized person has from five to six quarts of blood in his body. All of it is contained in a closed system of tubes called *blood vessels.* Unless the walls of the blood vessels are cut or broken open, blood never flows outside of them. A black-and-blue mark resulting from a blow on the body is caused by blood which escaped from damaged blood vessels. The blood vessels and the *heart* make up the *circulatory system.*

The heart as a pump. The heart pumps the blood into vessels that extend throughout the entire body. The wall of the heart is made up of muscles, as shown on page 314. By the contraction and expansion of these muscles, the blood is forced through the four spaces or chambers in the heart, and into the vessels of the body. Each time this action occurs the heart is said to beat.

Food delivery to body cells. Blood can circulate through the body in less than one minute. It is, therefore, not very long after food enters the blood in the villi before it is delivered to cells of the body. Let us trace the passage of digested food from the small intestine to a muscle cell in the right arm of an active person. The blood picks up the food while flowing through capillaries in the villi of the small intestine. From the very tiny vessels of the capillaries, it flows into larger blood vessels called *veins,* which carry blood to the heart, and finally into one large vein that leads to the *liver.* As the blood from the villi passes through the liver, some of the food may leave the blood and be stored for future use. The remaining food is carried by the blood to the heart. The blood, pumped to the lungs through chambers on the right side of the heart, returns to chambers

The blood circulatory system of the body. The darker colored vessels are arteries and the lighter ones are veins. Capillaries branch off from arteries and connect with veins.





The direction in which blood flows as it is pumped through the four chambers of the heart and out into the body is shown by arrows. Blood from veins enters the right side of the heart, and is pumped from there into the arteries in the lungs. It is returned from the lungs through veins to the left side of the heart and is then pumped to other parts of the body.

on the left side of the heart. It is then pumped out of the heart through blood vessels called *arteries* which extend to every part of the body. The food which we started to follow from the villi is now pumped with the blood through an artery into the right arm.

Cells cannot obtain food from the blood as long as it is in an artery, since the walls of arteries are too thick. The blood continues to flow through thick-walled arteries into smaller and smaller arteries with thinner walls in the muscle tissue. Soon it reaches one of many capillaries in the muscles and finally reaches the protoplasm of cells, as shown on page 315.

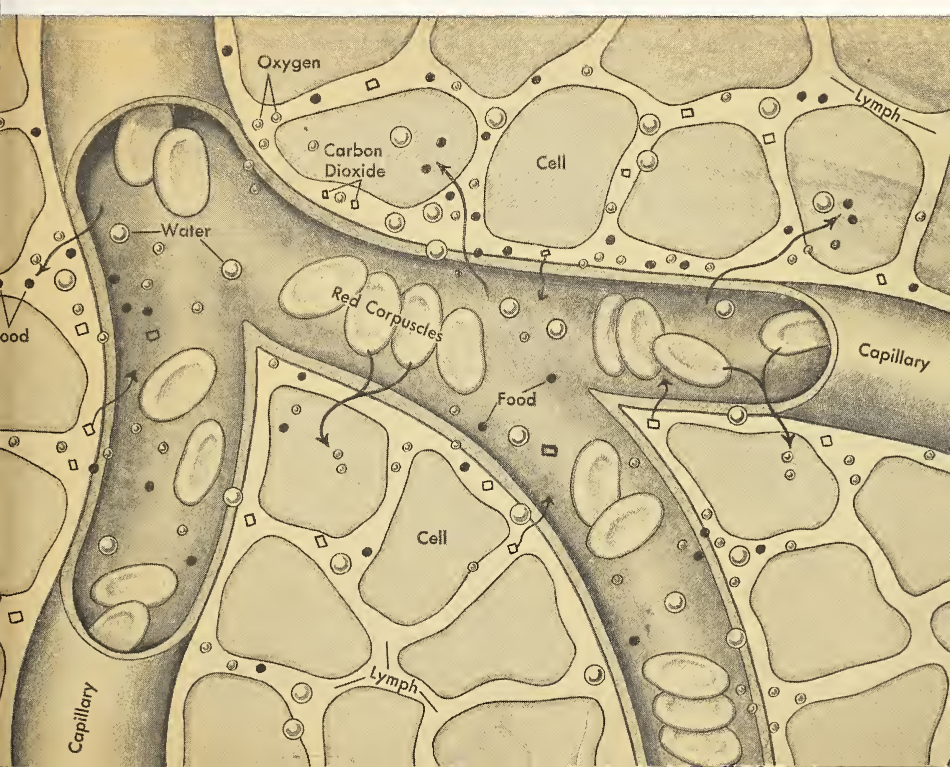
In the same way, the blood transports food to all cells of the body. Certain cells store surplus food, either in the form of animal starch or as fat. When there is not sufficient food in the blood to supply the demands of cells, food is released from storage.

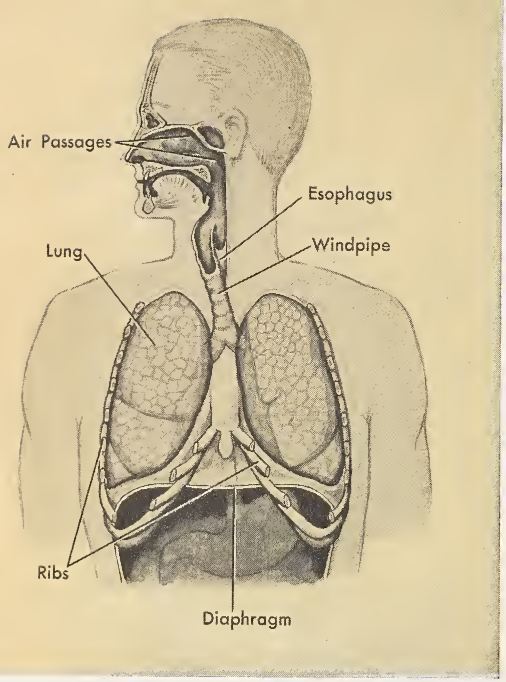
The blood delivers oxygen. Before cells of our bodies can obtain energy from food, the food must combine with oxygen or be oxidized. A constant supply of oxygen is therefore needed by all cells of the body. The oxygen is obtained from the air we breathe and is delivered to cells by the blood. The diagram on page 316 will help you understand how air is taken into the lungs through the windpipe and forced out of the lungs.

There are millions of tiny air sacs in the lungs. After blood enters the heart from the body, it is pumped into capillaries surrounding these air sacs. The oxygen from the air in the lungs passes through the thin walls of the air sacs and the thin walls of the capillaries into the blood. There the oxygen combines with a substance called *hemoglobin* in the red blood cells or *corpuscles* and is carried by them to other capillaries throughout the body. Through capillary walls, this oxygen passes into the lymph and then into the cell (see below).

Wastes are removed from cells. When food is oxidized, water and carbon dioxide are given off as waste products. Other wastes, containing nitrogen, are also given off by cells as protoplasm is worn out and as protein foods are used to produce energy. In order for the cells to continue to operate properly, all these wastes must be carried away. This is another service performed by the blood: it transports the waste material. The wastes pass from the cells through the lymph and capillary walls into the blood. The blood flows on through small veins which lead into larger veins until the blood with wastes is returned to the heart.

Digested food and water from the blood and oxygen, which is carried by red corpuscles in the blood, pass through the walls of capillaries into the lymph, where they become available to body cells. Carbon dioxide from body cells follows the same path back to the blood and is then carried to lungs, where it is given off as a waste product. Note the labels for each thing shown in the diagram below.





As the diaphragm is lowered and the ribs raised the chest cavity is enlarged and air rushes into the lungs through the windpipe. When the action is reversed, air is forced out of the lungs.

One of the heart chambers pumps the blood into capillaries surrounding air sacs in the lungs. Here the carbon dioxide and some water passes from the blood into the air sacs of the lungs and is breathed out.

Nitrogen wastes are removed from the blood as it is pumped through blood vessels in the kidneys. The wastes are collected in tubes as *urine,* and the urine is stored in the bladder until passed from the body. Smaller amounts of nitrogen wastes are contained in sweat or perspiration, which consists largely of water. *Sweat glands* (see page 317) remove these wastes in perspiration.

Regulation of body temperature. In Chapter 13 we learned that the temperature of the body is maintained at about 98.6° F. Let us now see how the skin functions as one of the important heat regulators for the body. Note the blood vessels in the drawing, page 317. When the body becomes too warm, these vessels expand, carrying more blood to the skin. This causes the skin to become flushed or red, as you have probably noticed on a warm day. With more blood near the surface of the body, heat can be lost more rapidly by one of the four ways you have previously learned: by conduction, by radiation, by convection, or by evaporation. Whenever the body becomes cold, the blood vessels in the skin contract, and body heat is conserved.

CONTROL OF BODY ACTIVITIES

In order for the body to function efficiently, its many activities have to be controlled. Digestive juices must be produced when food is passing through the mouth, stomach, and intestines. The heart must beat regularly to pump the blood. Breathing must occur at regular intervals. When wastes accumulate, they must be eliminated. Body heat must be regulated.

The nervous system and chemical substances, called *hormones,* control both the time and the rate at which body activities occur. The nervous system also controls all other activities of the body such as walking, talking, reading, and thinking.

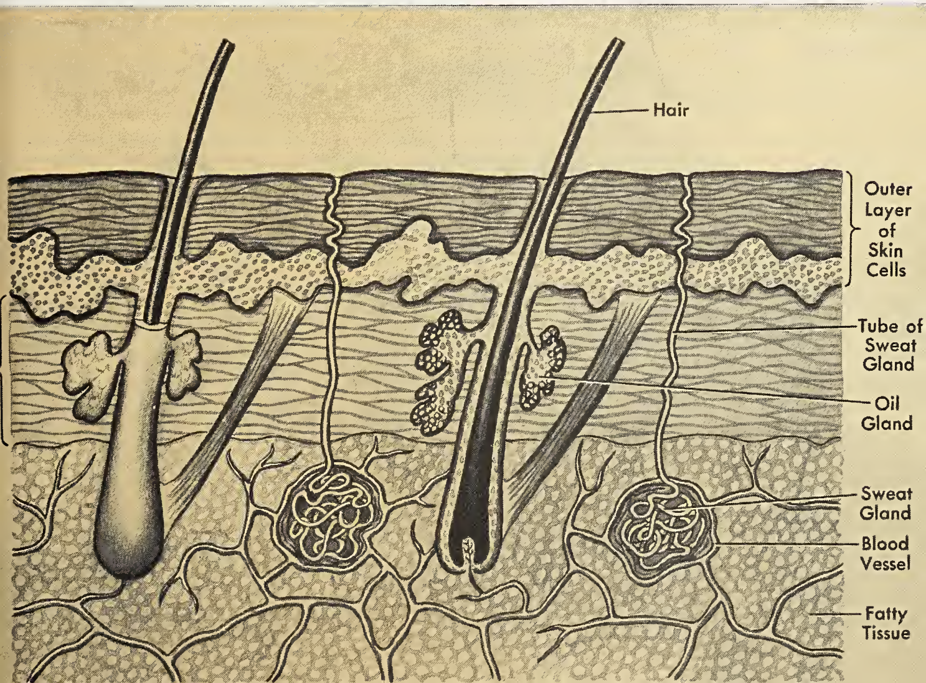
The nervous system. The nervous system is made up of many nerve cells. As you will recall, they are long cells, and there are some in every part of the body. They are more *sensitive* than other kinds of cells; that is, they are more easily affected by contact, chemicals, temperature, light, sound, and other such conditions, called *stimuli.* These stimuli affect nerve cells in such a way that they are able to pass the effect on as nerve messages from one nerve cell to another. A thin strand of several nerve cells is called a *nerve.*

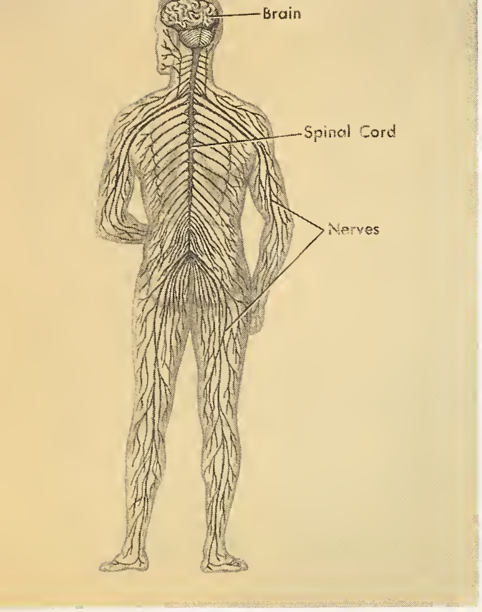
There are special nerve centers in the body, each made up of a large number of cells, and each controlling certain activities. A group of nerve centers near the spinal cord controls the action of the heart, liver, stomach, kidneys, small intestine, and large intestine. These nerve centers, along with the brain and spinal cord, control all the activities of the body. (See page 318.)

Sense organs. In order for the body to operate properly, it must be sensitive to those conditions in its environment which affect it. Nerve cells located in different parts of the body respond only to certain kinds of stimuli in the environment. Some nerve cells in the skin are affected only by temperature, others by something touching them. On nerve cells in the eyes only light has an effect. Other nerve cells located in the nose are affected only by gases, and those in the ear only by sound. Parts of the body, such as the skin, the eyes, and the ears, which are sensitive to stimuli, are called *sense organs,* and through them we learn about our surroundings.

Kinds of actions. Nerves extend from the sense organs to nerve centers in the spinal cord or brain. Others extend from the brain and spinal cord to the muscles of the body that can act. While you are reading this page, nerve messages are being sent from your eyes to your brain so that you see and understand what you read.

Diagram of a cross section of the skin greatly enlarged.





Drawing of the nervous system, showing the brain, spinal cord, and some of the nerves. Nerves extend to every part of the body where they aid in controlling the many kinds of activities carried on by the body.

Reading is called a *voluntary act* because you are thinking while you read. If while you were reading someone dropped a book beside you, you would probably jump without thinking about what you were doing. This is how it would work: Your ear would pick up the air vibrations, set up by the book hitting the floor, and send a message to your spinal cord. Rather than the message going to the brain for thought, nerve cells in the spinal cord would carry it to the muscles of your body, and that would cause you to jump. This is called an *involuntary act,* an act that you do without thinking.

Do you remember when you were learning to tie your shoes or maybe ride a bicycle? Every movement you made was carefully thought out. Soon you got to the place where you could tie your shoe or ride your bicycle without ever thinking about what you were doing. The action became involuntary; however, it was learned first. Many of your actions which used to be voluntary have through continued practice become involuntary, and are called *habits.*

Hormones also regulate. Hormones are chemical substances that regulate certain activities in the body. Produced by several glands (see page 319), hormones are carried throughout the body in the blood stream. Certain hormones produced in the *pituitary* gland and the *thyroid* gland regulate growth. Another (*insulin*), produced by cells in the pancreas, regulates the rate at which sugar is used in the body. A hormone (*adrenalin*), produced by the *adrenal* gland, which speeds up body activities, may cause a temper tantrum or other expressions of emotions. Other hormones control the production of digestive juices. Your development into adult men and women is also controlled by hormones. These chemical substances have many different effects upon the body, not all of which are understood.

GROWTH OF THE BODY

We have seen how many of the essential processes of the body take place, and how they are controlled to keep the body operating properly. Let us examine now the way the body grows. Growth is most important to all of us, and especially important to boys and girls.

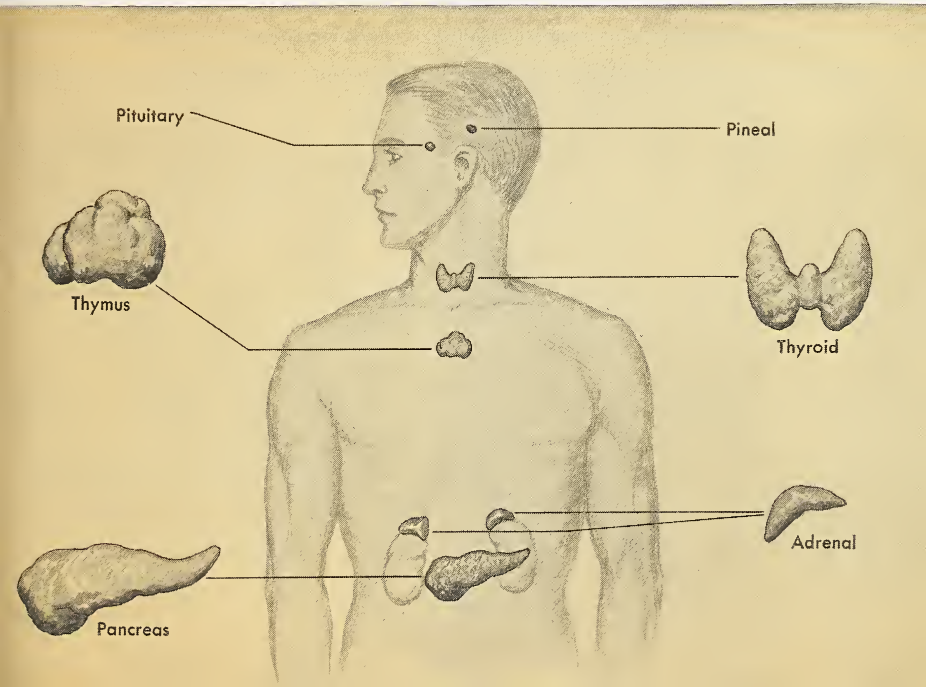
Can you recall when you were much smaller than you are now? Do you remember how anxious you were to grow up? At times you probably doubted that you would ever get any taller because the process seemed so slow. But you did get larger, and you will continue to grow for several more years. Girls do not generally complete their growth until they are about eighteen years old, boys about twenty years old.

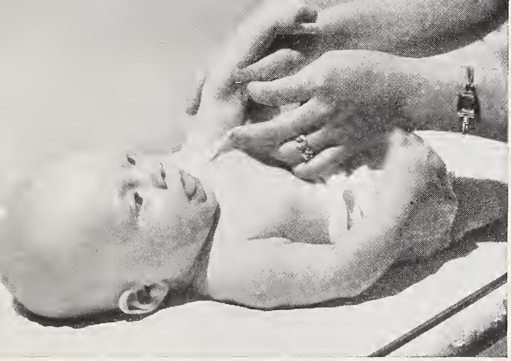
Cell growth. Although there are many questions about growth still unanswered, we do know something about the process. It takes place in the cells, the body growing as the number and size of its cells increase. The number of cells is increased by cell division, as shown on page 324. But this alone would not result in growth unless each new cell also became larger. In order for a cell to become larger, the amount of protoplasm in it must be increased. Protoplasm in cells accomplishes this by changing chemically the digested food brought to the cells by the blood. Just how all of these chemical processes take place no one has been able to answer completely.

Growth may also result from body cells taking in water and becoming larger. You have probably heard of people losing weight as a result of very vigorous exercise. Most of such a decrease in weight is a result of water being lost by perspiration. In such cases people regain their weight rapidly (or grow) by consuming additional water after exercise.

Teeth and bones. The body may also grow when certain cells form nonliving substances in various parts of the

The approximate location of several of the glands producing hormones which aid in regulating certain body processes. Excepting the thymus and pineal, the important functions of the glands shown here are described in the text. The function of the pineal is not understood; the thymus may have something to do with growth.





Doris-Pinney from Monkmeyer

Our growth is a natural body process and results in many changes. These are pictures of the same child at four months and three years of age. He has not only increased in size, but has changed in other ways.

body. The formation of teeth and bone is an illustration of such growth. The manner in which bone is formed has already been described (see page 308). Teeth are also formed from cells that deposit substances to make the teeth hard. Both the bony framework, *dentine,* and the outer hard coating, *enamel,* of teeth are formed this way.

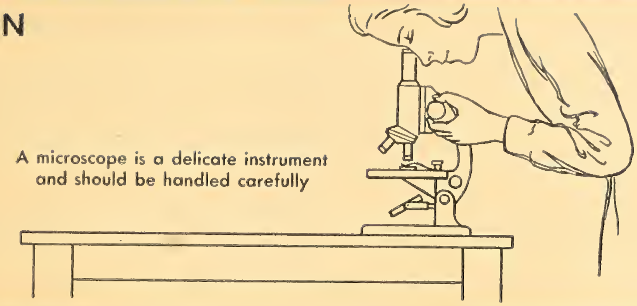
Although the rate and amount of growth is regulated by hormones, as we shall see in the next problem, the materials for growth must be supplied by the food we eat.

SUMMARY

The human body is made up of cellular units of protoplasm. Each type of cell has a special kind of work to do in carrying on the activities of the body. All movements of the body are accomplished by muscles, which need energy in order to act.

Cells must produce more protoplasm in order to grow and to replace worn-out protoplasm. Both energy for action and materials for growth and repair are supplied by food. But food must be digested and transported to cells before it can be so used. Foods are digested by a chemical process that changes the nature and size of molecules of food. Energy is obtained from digested food by another chemical process when oxygen is supplied to the cells. When cells carry on the life activities of the body, wastes are produced and must be eliminated. Food may be supplied to cells, and wastes eliminated because certain membranes of the body permit the passage of water and materials dissolved in water. All of these activities are regulated by the nervous system and hormones.

OBSERVATION



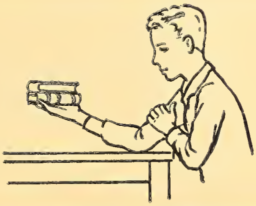
A microscope is a delicate instrument and should be handled carefully

What to observe. Cells from your own body.

How to observe them. Scrape the inside of your cheek with a clean tooth pick, and rub the scrapings off into a drop of water that has been placed on a clean microscope slide. Add a few drops of iodine solution. Smear smoothly over about one-third of the slide and observe under a microscope.

Interpretation of your observation. What shape are the cells? Why was iodine solution added? Each type of cell has a special function in our bodies. What function would you think these cells performed? In one sentence, write a description of the cells which line your cheek.

OBSERVATION

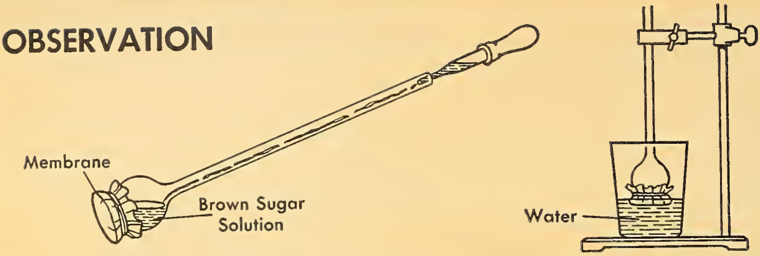


What to observe. The actions of joints and muscles.

How to observe them. Place your left hand on your right shoulder and feel the action as you move your right arm through a great many different positions. What kind of a joint provides the action you observe in your shoulder? Feel the action of your elbow as you move your forearm through as many positions as possible. What type of joint provides the action you observe in your elbow? With your left hand, feel the action of the muscle between your elbow and shoulder as you raise and lower an object with your right hand while your right elbow is resting on a table. What muscle action makes it possible for you to move the object?

Interpretation of your observation. Write one sentence stating how the joints and muscles work together to enable you to move your arms through the various positions used in this observation.

OBSERVATION



What to observe. The effect of sugar and water passing through a membrane.

How to observe it. Fasten a piece of sausage skin or goldbeater's membrane over the end of a thistle tube with a rubber band. Fill the bowl of the tube with brown sugar solution, as shown in the diagram. Invert the thistle tube into a glass of water, keeping rubber band above water, and fasten to a ringstand. Observe for at least half an hour.

Interpretation of your observation. The sausage skin is similar to the wall of the small intestine. It contains very small openings through which molecules of water and sugar can pass. How can you tell that water passes through the membrane? How can you tell that sugar passes through the membrane?

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. All the activities of living things are carried on by (a) protoplasm within the cells; (b) cell walls; (c) the spinal cord; (d) new cells.
2. The bony framework for the body is known as the (a) spinal cord; (b) bones; (c) skeleton; (d) vertebrae.
3. The chemical process of changing complex food molecules into simpler ones that can be used by the body is called (a) circulation; (b) elimination; (c) digestion; (d) respiration.
4. That part of the body which is *not* concerned with getting food ready

for use by the body is the (a) stomach; (b) intestine; (c) pancreas; (d) lungs.

5. The red blood cells carry (a) food to the body cells; (b) oxygen to the body cells; (c) nitrogen wastes away from the cells; (d) water to the cells.
6. The body cells which are most sensitive to stimuli are the (a) muscle cells; (b) bone cells; (c) red blood cells; (d) nerve cells.
7. Chemical substances which help regulate the activities of the body are called (a) lymph; (b) hormones; (c) blood; (d) hemoglobin.
8. The body grows (a) by perspiring; (b) by removing wastes; (c) by exercising; (d) by increasing the number and size of its cells.

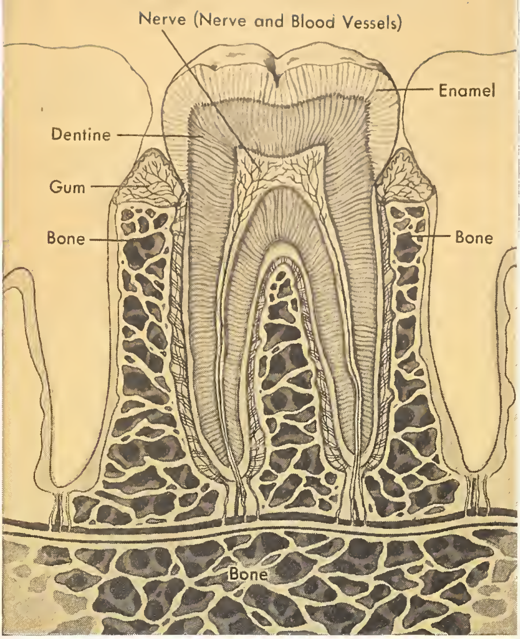


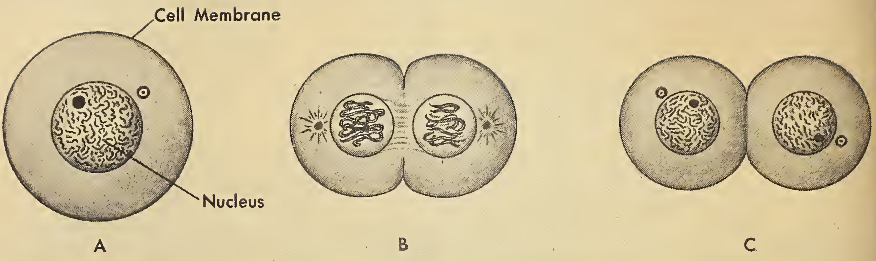
Diagram of a cross section of a tooth showing how it is constructed and the manner in which it is held in place within the bone of the jaw.

PROBLEM 2. How can we help our bodies to operate more efficiently?

OUR FOOD NEEDS

Although you have little direct control over most of the important processes of your body, many of your daily activities have an indirect effect upon them. Body processes are affected by the types of food you eat; how much you eat; your work and play activities; the amount of rest you get; and even the type of clothing you wear. In this problem, you will see how body processes are affected by your daily activities and what you might do to help your body operate more efficiently.

Essential nutrients. The food substances that supply the body with energy and materials for growth and repair are called *nutrients.* We have already discussed three types of nutrients. The starch and sugar in food are grouped together into one type called *carbohydrate.* Protein is a second type of nutrient, and fat a third. As you will recall, food made up of carbohydrates, fats, and proteins may be used in the body to supply energy. Proteins are also the nutrients used by protoplasm to build and repair tissues. If the carbohydrates and fats taken into the body are not used immediately to supply energy, they may be stored in the body as animal starch or as fat.



When a body cell begins to divide, the nucleus goes through a number of changes which result in the formation of two nuclei, as shown in B. Each becomes the nucleus of a new cell, as shown in C. More protoplasm has to be added to the new cells before each of them will be as large as the original, or mother, cell.

Two other types of nutrients are necessary in order to keep the body operating properly. Certain chemical elements, such as calcium, copper, iodine, iron, and phosphorus, are often called mineral nutrients because most of them are obtained by the body from minerals in food. These are used in building body tissues and regulating body processes. The fifth type of nutrient, *vitamins,* is one you have probably heard about most frequently.

Although the body does not obtain energy or building materials from water, none of the nutrients could be used in the body without it. As you will see later, a large part of the body is made up of water, and it is needed to carry on all body processes.

Energy foods. Foods differ greatly in the amount of energy they will supply. In order to compare the energy value of foods, some measurement of energy is necessary. As you will recall from Chapter 12, the amount of energy fuels can produce is measured in heat units called calories. The energy value of foods is also expressed in Calories. (This unit is the large Calorie which is equal to 1,000 small calories.) The number of Calories which a particular food, such as bananas, will supply is determined by using the calorimeter described on page 234. The table on page 325 shows the number of Calories and nutrients in some foods.

Energy needs of young people. The amount of energy a person must obtain from his food depends upon his size, age, sex, and on how active he is. Girls between thirteen and fifteen years of age require 2,600 Calories a day. Boys of the same age need 3,200 Calories. Girls between sixteen and twenty years of age require 2,400 Calories, whereas boys of that age need 3,800 Calories. Boys, therefore, must have more food to supply the additional Calories they need.

If a person does not eat sufficient food of the right kind to supply him with necessary energy, he will lose weight. The fat stored in his body will be used to supply the needed energy. If he eats more food than is needed to supply energy, the extra food will generally be changed into body fat, causing him to gain weight. It is usually a good idea for boys and girls to have some extra fat in their bodies. Much of it

NUTRIENT CONTENT AND NUMBER OF CALORIES IN AN AVERAGE PORTION OF VARIOUS FOODS AND BEVERAGES[1]

	PERCENTAGE BY WEIGHT			AVERAGE	TOTAL
FOOD	PROTEIN	CARBOHYDRATE	FAT	PORTION	CALORIES
Avocados	1.7	3.7	26.4	½ pear	259
Bacon (lean)	12.2	1.4	53.0	4 slices	149
Beans, baked	6.0	17.8	0.4	½ cup	99
Beef roast	19.2	0.0	22.0	¼ pound	303
Beek steak	18.7	1.4	17.0	¼ pound	263
Bologna	14.8	3.6	15.9	4 slices	93
Bread, white	8.5	52.0	2.0	2 slices	130
Bread, whole wheat	9.5	47.0	3.5	2 slices	129
Butter	0.6	0.4	81.0	2 pats	103
Cake, sponge	7.9	54.2	5.0	1 piece	108
Cheese, American	23.9	1.7	32.3	1 slice	110
Cocoa (milk)	4.9	11.9	5.5	1 cup	211
Eggs	12.8	0.7	11.5	one whole	82
Frankfurters	15.2	3.3	14.1	2 links	227
Ginger Ale	—	9.0	—	1 bottle	61
Halibut	18.6	0.0	5.2	¼ pound	81
Ham (fat)	14.6	0.3	44.0	¼ pound	515
Hominy, white	8.5	78.5	0.8	¼ cup	178
Ice cream (vanilla)	3.9	20.3	13.0	½ cup	214
Margarine	0.6	0.4	81.0	1 tablespoon	103
Milk, whole	3.5	4.9	3.9	1 glass	145
Oatmeal	14.2	67.0	7.4	¼ cup	98
Olives, green	1.5	2.8	13.5	5 small	35
Oranges	0.9	10.6	0.2	½ cup juice	48
Peaches, yellow	0.5	11.4	0.1	1 large	49
Raisins	2.3	69.5	0.5	⅓ cup	131
Rice, white	7.6	79.2	0.3	2 tablespoons	98
Root Beer	—	8.0	—	1 bottle	54
Strawberries	0.8	6.9	0.6	12 berries	36

[1] Adapted from *Nutritional Data,* Mellon Institute of Industrial Research, Pittsburgh 13.

will be stored in layers of tissue lying underneath the skin, which help keep the body warm and improve the appearance.

Proteins for growth. Boys and girls generally need more proteins than grown men and women. It has been estimated that adult men need about 70 grams of protein a day whereas boys between the ages of thirteen and fifteen years need 85 grams. Adult women need about 60 grams of protein a day but girls between thirteen and fifteen years of age need 80 grams. These additional amounts of protein needed by boys and girls supply their bodies with materials for growth. Protein is the only type of nutrient that will supply many of the materials essential for growth.

Vitamins for health. The results of controlled experimentation have proved that nutrients other than carbohydrates, fats, proteins, and minerals are essential for good health. Some of these early experiments were as exciting as a science fiction story because of the dramatic results obtained. When you read about the experiments that proved that a lack of certain vitamins resulted in diseases such as beriberi, rickets, and scurvy, you wonder why it took so long for man to find out these things. But once the first discovery was made, the search for additional ones was carried on in a most diligent manner by other scientists. In fact the discoveries have come so rapidly in the past fifty years that there has been some confusion about naming them. For this reason you will find that certain vitamins such as B_1 (*thiamin*) has at least two names.

Information about some of the vitamins that are considered necessary to keep the body operating properly is included in the table below. Many more vitamins have been discovered some of which are believed to affect human beings. These include Vitamin B_6 and B_{12}, and *folic acid,* and *pantothenic acid.* As you will note in the table, each vitamin has a definite effect upon the body. Most vitamins are stored in the body; others like vitamin C (*ascorbic acid*) are not. Therefore a daily supply of those not stored in the body is needed.

Minerals for health. When food such as meat, potatoes, or bread is completely burned, only a powdery ash remains, consisting of the minerals that were in the food. Certain chemical elements from these minerals are necessary

SOME HEALTH EFFECTS AND FOOD SOURCES OF VITAMINS

VITAMIN	SOME HEALTH EFFECTS	SOME FOOD SOURCES
A	Aids growth and vision; builds resistance to infection; prevents sore eyes and night blindness	Broccoli, carrots, chard, cod liver oil, peppers, spinach, sweet potatoes, butter or margarine, eggs
B_1 or Thiamin	Aids growth; stimulates appetite; essential for normal condition and functioning of nerve tissue; prevents *beriberi*[2]	Bran, enriched bread,[1] whole grains, liver, lean meat, nuts, yeast
B_2 or Riboflavin	Improves growth; essential in nerve tissue; promotes general good health	Enriched bread; broccoli, cheese, eggs, milk, lean meat, oysters, prunes, yeast
Nicotinic Acid Niacin	Promotes growth and general health; maintains normal functioning of digestive system and skin; prevents *pellagra*[2]	Bran, fish, heart, kidney, liver, lean meat, wheat, bread, milk, potatoes, spinach
C or Ascorbic Acid	Aids in development of good teeth; improves appetite; promotes growth; helps protect body from disease; prevents *scurvy*[2]	Broccoli, citrus fruits, raw cabbage, cauliflower, peppers, pineapple, strawberries
D	Aids body in using calcium and phosphorus in building strong bones; prevents *rickets*[2]	Irradiated foods such as milk and margarine; halibut liver oil, sardines, tuna, butter
E	Believed to be important in human reproduction	Cottonseed oil, corn oil, lettuce, peanut oil, meat, milk, and eggs
K	Aids in clotting of blood	Cabbage, cheese, cauliflower, spinach, liver, tomatoes

[1] Some breads and cereals which have B vitamins added are said to be *enriched*.
[2] See page 338.

to the body if it is to operate properly. The table below, which lists their effects on the body and the foods from which they may be obtained, should be carefully studied. For example, calcium, as you have learned, builds bone

SOME HEALTH EFFECTS AND FOOD SOURCES OF MINERAL ELEMENTS

MINERAL ELEMENTS	SOME HEALTH EFFECTS	SOME FOOD SOURCES
Calcium	Used in building bones and teeth; aids in proper functioning of heart, nerve, and muscles; aids in clotting of blood	Bread, broccoli, cauliflower, cheese, ice cream, milk, beans, peas, carrots, cabbage, egg, shellfish, turnips
Chlorine	Aids digestion	Bread, cheese, clams, crackers, ham, pretzels, sauerkraut, eggs, milk
Cobalt	Aids growth, appetite, condition of skin, production of red corpuscles	Liver, seafoods, leafy vegetables, whole grains
Copper	Essential in formation of hemoglobin and stimulates growth of red blood cells; helps prevent anemia	Liver, mushrooms, shellfish, bran, bread, eggs, meat, nuts, oatmeal, leafy vegetables
Iodine	Essential in normal functioning of thyroid gland; protects from goiter	Cod liver oil, salt-water fish, iodized salt, vegetables, cereals, dairy products and fruits produced on soils of good iodine content
Iron	Essential in formation of hemoglobin	Apricots, egg yolk, heart, liver, kidney, bananas, oatmeal, potatoes, raisins
Magnesium	Important for muscle activity, bone structure and nerve functioning	Beans, Brussels sprouts, clams, nuts, peas, spinach, beef, milk, potatoes
Manganese	Essential for normal growth	Bananas, beets, celery, dates, liver, oatmeal, tomatoes
Phosphorus	Essential in building bones and teeth	Bran, cheese, egg yolk, grains, meat, milk, shellfish, turnip, and mustard greens
Potassium	Essential for normal growth	Cheese, eggs, liver, macaroni, milk, nuts, oatmeal, seafoods, prunes, raisins
Sodium	Regulates water content of cells	Bread, clams, crackers, oysters, whole grains, milk
Sulfur	Required for the formation of body proteins used in producing tissues	Cheese, eggs, lean meat, shellfish, bread, milk
Zinc	Required for normal growth and development of hair	Beans, dandelions, liver, oysters, spinach, beets, potatoes

and teeth; growing young people especially need this element, an excellent source of which is milk. A lack of iodine to make the thyroid gland function properly causes a disease known as *goiter*. Iron helps in the formation of essential hemoglobin. As the table shows, each element does a special job.

Water for life. By now you have probably recognized the importance of water to the body. Three fourths of the soft tissue of the body is composed of water. None of the life processes of the body could take place without water. Food must be mixed with water before it can be digested, and digested food must be dissolved in water before it can be transported to cells by the blood. Water is the basic fluid of blood and lymph. It aids in carrying red blood cells with their loads of oxygen through vessels of the body. Oxygen enters cells of the body through a path of water, and waste materials are given off through it.

MEETING OUR FOOD NEEDS

Balancing your diet. You are probably beginning to wonder how it is possible for a person to obtain the nutrients necessary to keep the body operating properly. It is not difficult. Examine again the Food Sources column in the tables on pages 326 and 327. Note the many different types of food in which the essential nutrients are found.

When the day's meals are planned to include all the nutrients in the amounts needed for good health, it may be said that you are obtaining a *balanced diet*. In order to help you select a balanced diet, food scientists called *nutritionists* recommend that some foods from each of seven different food groups be selected each day, in the amounts shown on page 329. Everyone concerned about good health should check his diet frequently against these basic seven.

Problems with diet. Have you ever been told that you were too small or too big for your age and, therefore, were not eating properly? Maybe the person who told you this was right and maybe he was wrong. How can you tell?

If you were to compare the heights and weights of boys and girls in your class, you would find a wide range of differences. Young people of your age vary greatly in their patterns and rates of growth. It is possible that there aren't two people in your class that have grown at the same rate. An "average" or "normal" height and weight for persons of your age has no meaning. Each of you sets his own pattern. For you that pattern is normal. Height and weight charts that do not take these facts into consideration are misleading and should not be used. If you feel that you may not be gaining weight as you should or that you may be getting too fat, you should talk with your doctor. Beyond taking care to select a balanced diet and to eat three good meals a day, one should not experiment upon himself by going on some "special diet" that he has heard about.

Persons who become tired easily may not be eating enough food to supply the amount of energy needed to carry on their activities, or their diet may lack essential minerals and vitamins. Some people are very sensitive, or *allergic*, to certain types of food, which may cause a rash to form on their bodies or make them quite ill. In such cases the diet has to be carefully checked by a doctor to determine what food is causing the difficulty.

Constipation may indicate that there is not sufficient *roughage* and other materials in the diet. Roughage is the indigestible parts of food which pass through the digestive system into the large intestine. Considerable amounts of it are contained in cereals, fruits, and vegetables. Roughage helps to fill the large intestine, thus causing movements in the intestinal walls which help to eliminate the intestinal wastes. On the other hand, too much roughage may irritate the lining of the intestine and thus be harmful. Such foods as orange juice and prunes contain substances other than bulk which aid in movements of the large intestine.

Safeguarding the vitamin and mineral supplies. Some vitamins in foods may be destroyed when the food is exposed to air. Vitamin C, for example, combines with oxygen or oxidizes when exposed to the air, and forms a new chemical compound which has no value to the body. Fresh vegetables should therefore be kept in cool places and covered to prevent loss of precious vitamins. Peeled fruits and vegetables should not be left exposed to the air very long before they are to be used.

Minerals and some of the vitamins in vegetables dissolve in the water in which the vegetables are cooked. If this liquid is thrown out, so are the vitamins and minerals. Other vitamins are destroyed by being kept at high temperatures for long periods of time. In general, foods should be cooked in a small amount of water, at the lowest possible temperature for as short a time as possible, and with the least surface exposed to the air.

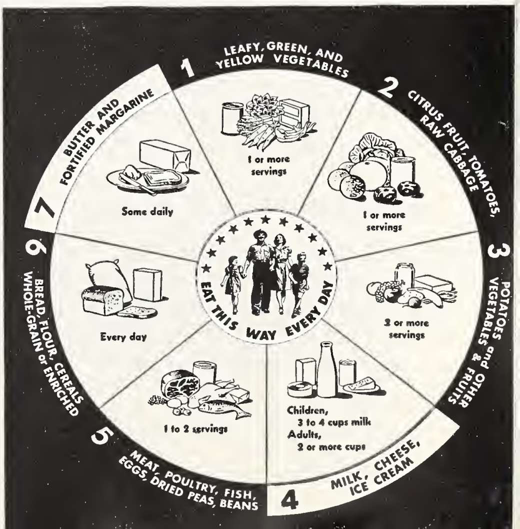
Considerable amounts of vitamin B_1, or thiamin, may be destroyed when some canned foods are heated to high temperatures in order to preserve them. Vitamins are not readily destroyed by low temperatures, and properly frozen foods retain most of their vitamins. Dehydration or drying foods usually destroys more vitamins than any other method of preserving foods.

A knowledge of all these food facts just discussed will help you place proper value on food advertisements. Some of them are really informative, some misleading. If a person thinks he needs vitamins or minerals in addition to those he obtains from a well-balanced diet, he should consult his physician rather than buy preparations that are claimed to be "good for him."

Eating habits. The way a person eats, the amount of food he eats at one time, the number of times a day he eats, and the conditions under which he eats have an effect upon the functioning of the body. You have seen why

The Basic Seven—daily food needs.

U. S. Department of Agriculture


1 LEAFY, GREEN, AND YELLOW VEGETABLES
1 or more servings
2 CITRUS FRUIT, TOMATOES, RAW CABBAGE
1 or more servings
3 POTATOES and OTHER VEGETABLES & FRUITS
2 or more servings
4 MILK, CHEESE, ICE CREAM
Children, 3 to 4 cups milk
Adults, 2 or more cups
5 MEAT, POULTRY, FISH, EGGS, DRIED PEAS, BEANS
1 to 2 servings
6 BREAD, FLOUR, CEREALS WHOLE-GRAIN or ENRICHED
Every day
7 BUTTER AND FORTIFIED MARGARINE
Some daily
EAT THIS WAY EVERY DAY

thorough chewing of food (*mastication*) is important. To chew well, it is necessary to avoid filling the mouth too full or eating too rapidly. Eating too much at one time is a bad practice also, because overfilling the stomach may cause the lining to become inflamed, resulting in indigestion.

Eating between meals may be undesirable for several reasons: it may add unnecessary fat to the body and lessen the appetite for food at regular mealtime, thus preventing you from eating enough wholesome food. Candy or any other "sweet" generally eaten between meals may supply energy for the body, but contains few of the essential vitamins.

It has been demonstrated that excitement, fear, worry, and anger interfere with digestion. Therefore, one should not eat when he is in any of these emotional conditions; mealtime should be enjoyable and leisurely.

Food misconceptions. Whenever people believe something that is not true, it is said that they have a *misconception*. There are many misconceptions about the effects different kinds of food have upon the body. If you are thinking scientifically, you will hesitate to accept statements that cannot be supported with facts. The books on foods listed at the end of this unit have been written by authorities and should be used to check the truth of any statement you may doubt about foods.

HELPING IN OTHER WAYS

Proper clothing. One important reason for wearing clothing is to aid in regulating the transfer of heat to and from the body. The way different types of clothing affect heat transfer was discussed in Chapter 13. The color of clothing and the type of fabric from which it is made, as well as the amount of clothing worn, affect heat transfer from the body. During the winter months it is important to wear lighter clothing in heated buildings and a heavier garment outside to prevent the body from being cooled too rapidly. This is especially important if you have been taking part in indoor sports.

Exercise. Exercise is necessary for the proper development and control of muscles. Through frequent exercise, the young child learns to control his muscles so that he can walk without wobbling. Athletes and dancers exercise their muscles for a long time before they develop the control and strength necessary to be outstanding performers.

Physical activity develops strong heart muscles and good circulation. Proper development of the lungs is also dependent upon activities which exercise the muscles controlling their use. Exercise helps develop an appetite and aids in eliminating wastes from the body. It also helps the body to relax and to overcome fatigue from mental activity. By strengthening muscles across the abdomen, shoulders, and back, exercise improves the posture.

Rest. Periods of rest are most essential in keeping the body operating properly. Tiredness or *fatigue* results when muscle cells and nerve cells are active and release energy. Waste products harmful to the cells are then given off and have to be removed. During vigorous physical exercise, when wastes are produced faster than they can be removed and accumulate in large amounts, the body becomes fatigued. Rest is then necessary in order for the body to handle these wastes properly.

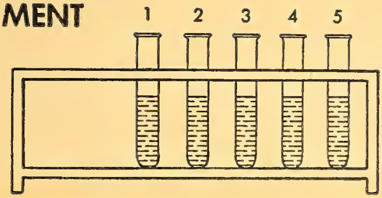
Those who take part in athletics of various kinds should be particularly careful not to exhaust their bodies. The desire to win or to become the best player has been known to cause young people to continue to play the game until serious damage has been done to their hearts. Overexertion is especially dangerous when the body is not in good physical condition. At the beginning of the season, good athletes "break in" slowly. This gives their bodies an opportunity to build up gradually to the place where they can play a hard game without doing any permanent damage.

SUMMARY

In order for the body to work efficiently, it must be supplied with the proper nutrients. Some nutrients are used in supplying energy and building up the body, others in regulating the activities of the body, including the rate at which it grows. The amount of different nutrients that an individual should obtain from his foods depends upon his size, age, sex, and the kind of activities in which he engages. The advice given about food by many people should be carefully checked with authorities before it is accepted as true. Meals eaten regularly under pleasant conditions make it possible to obtain the greatest value from food.

Health, gracefulness of movement, and personal appearance are improved by properly exercising the muscles of the body. Harmful wastes are produced from muscle activity and periods of rest are necessary in order that they may be removed.

XPERIMENT



Question to be answered. How can we identify sugar, starch, protein, and fat?

What you need. Five test tubes; glucose sugar; cornstarch; egg white; butter; Benedict's solution; iodine solution; nitric acid; ammonium hydroxide; small piece of white paper; source of heat, such as a Bunsen burner.

What to do. 1. Place a small amount of glucose in one test tube, cornstarch in the second, egg white in the third, and butter in the fourth. Add the same amount of water to each test tube. To a fifth test tube add the same amount of water and use this as your control. Add a few drops of Benedict's solution to each test tube, and boil the contents of each. Watch for color changes.

2. Clean the test tubes and again place a small amount of each food in them as you did above. Add some water and boil the contents of each tube. Add a few drops of iodine solution to each. Watch for color changes.

3. Clean the test tubes and again place a small amount of each of the foods in them, as you did above. Add some water to each test tube and a small amount of nitric acid. Boil the contents of each gently. Now add the same amount of ammonium hydroxide a drop at a time. Watch for color changes.

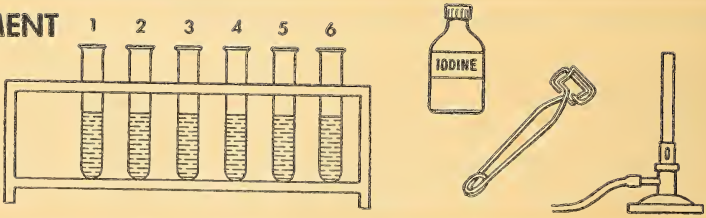
4. Rub a piece of white paper with a small amount of each of the four foods. Observe the effects of the food on the paper.

Your answer. How is the presence of glucose sugar, cornstarch, egg white, and butter shown in these tests?

Some assumptions in this experiment. 1. The evidence used to identify a nutrient was a result of only that nutrient.

2. What assumptions would you have to accept to use these tests on any food?

EXPERIMENT



Question to be answered. Will saliva change starch to sugar?

What you need. Test tubes; unsweetened crackers; water; Benedict's solution; iodine solution; test tube holder; source of heat.

What to do. Test pieces of cracker for starch and sugar. Test some class member's saliva for starch and sugar. Have him chew a cracker, mixing it thoroughly with saliva in his mouth. Have him note any change in flavor as he chews. Place some of the chewed cracker into each of two test tubes. Test the contents of one for starch and the other for sugar. Repeat the experiment using other members of the class.

Your answer. Why were unchewed crackers tested for starch and sugar? Why was the saliva tested before the cracker was chewed? How did the flavor of the cracker change as it was chewed? Were the results the same for each one who took part? How would you answer the experimental question?

Assumptions in this experiment. 1. Saliva acts on all starch as it did on the starch in these crackers.

2. All people's saliva will act this way.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The substances in food that are used by the body are called (a) diet; (b) allergies; (c) nutrients, (d) food misconceptions.
2. Carbohydrates are primarily used for (a) repairing tissues; (b) regulating body processes; (c) furnishing minerals; (d) supplying energy.
3. Because they are growing, boys have a greater need than men for (a) fats; (b) vitamins; (c) proteins; (d) water.
4. A person should chew food thoroughly because it (a) takes longer to eat when food is thoroughly chewed; (b) exercises the jaw muscles; (c) helps balance the diet; (d) aids digestion.
5. The proper development and control of muscles is obtained through (a) wearing stylish clothes; (b) eating plenty of vitamins; (c) vigorous exercise; (d) a combination of adequate rest, good diet, and proper exercise.

CHAPTER ACTIVITIES

REVIEW THE HUMAN BODY

Five major kinds of activities that must be accomplished by the body are listed below, followed by a number of different units of the body, such as cells, tissues, and organs. On your answer sheet, beside the letter of each unit, write the numbers of the activities primarily concerned. **Do not write in your textbook.**

ACTIVITIES OF THE BODY

1. Supporting itself
2. Carrying food to and waste materials from cells
3. Digesting food
4. Controlling its actions
5. Moving itself
6. Removing waste materials

UNITS OF THE BODY

a. Vertebrae
b. Spinal cord
c. Hinge joint
d. Bones
e. Ligaments
f. Muscles
g. Stomach
h. Nerves
i. Salivary glands
j. Blood
k. Sweat glands
l. Hormones
m. Pancreas
n. Plasma
o. Brain
p. Large intestine
q. Small intestine
r. Lymph
s. Kidneys
t. Lungs

SELECT GENERALIZATIONS

Below are listed two groups of statements. One statement in each group expresses the general idea to which the other statements of the group are related. Study each group of statements carefully, and write the number of the statement which expresses the general idea for that group in the proper place on your answer sheet.

Part 1

1. The blood carries oxygen to the body cells.

2. Body cells need food to grow and furnish energy.

3. Waste materials must be removed from body cells.

4. The blood carries digested food to the body cells.

5. The blood makes it possible for body cells to carry on their life activities.

6. The blood carries wastes from the body cells.

Part 2

1. The body needs certain minerals.

2. Vitamins are necessary for health.

3. Improper diet may cause one to tire easily, have skin rash or become constipated.

4. Carbohydrates are energy-producing nutrients.

5. Protein supplies the materials for growth.

6. The body operates most efficiently when supplied with the proper nutrients.

7. The body cannot carry on life processes without water.

Falk for New York Times

This research worker is handling tuberculosis bacilli to be used for study. She uses rubber gloves and a protective glass to avoid coming in contact with the bacilli.

chapter 18 CONDITIONS AFFECTING THE BODY

THERE are a number of reasons why young people today can look forward to enjoying a longer life than young people could a hundred years ago. More is known about the causes of many diseases. A great deal has been learned about the ways in which the body protects itself against them and how we can help it in its fight. Although it has become possible through our knowledge of some diseases practically to eliminate them, there are others, such as cancer, which even today are not completely understood.

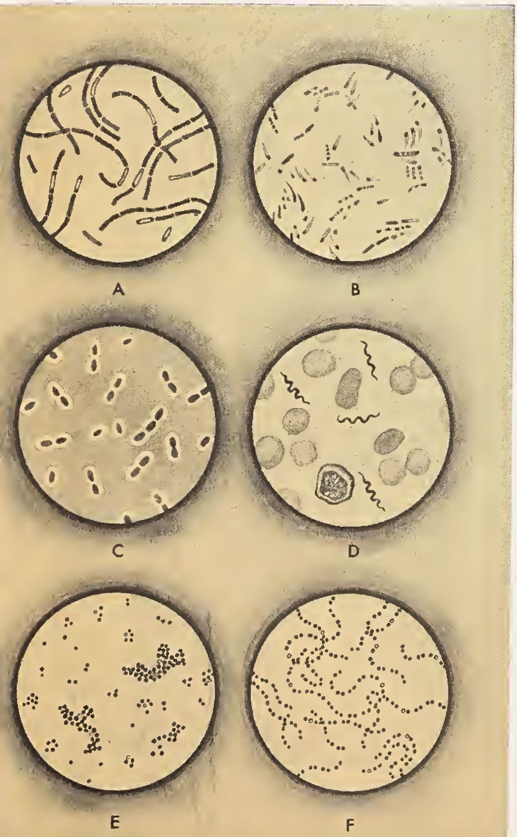
The effects of drinking and smoking upon the body have not been studied by scientists as intensively as diseases. Nor has the problem of narcotic drug addiction been considered as seriously as some other health problems. It is believed by some, however, that these are important problems for many young people. For that reason, some of the evidence obtained from work by authorities on these problems is presented in this chapter.

PROBLEM 1. How are diseases caused?

DISCOVERIES ABOUT DISEASE

Early ideas about the causes of disease. Before the real causes of disease were understood, people did many peculiar things to prevent themselves from becoming ill or to cure themselves after they had become ill. Early man believed such a dreadful experience as disease was caused by evil spirits getting into the body; special ornaments, called *charms,* were generally worn to prevent this from happening. Once a person became ill, attempts were made to drive out the evil spirits by beating drums and making weird noises; or hot needles and other sharp objects were used to make holes in the body so that the evil spirits could escape. Later, when it was believed that disease was caused by an overproduction of a substance called *black bile* in the body, attempts were made to remove this substance from the body. During another period, outdoor night air was accepted as being responsible for certain diseases, and people kept their houses tightly closed at night to keep it out.

Six disease-producing bacteria. A: anthrax; B: diphtheria; C: one type of pneumonia; D: ratbite fever; E: boils; F: pusformers.



Some people today are still influenced by many of these old beliefs regarding the cause of disease. They wear "good-luck" charms and other ornaments to prevent them from getting sick, or they shut out the night air which they believe is unhealthful. Have you heard of other beliefs such as these?

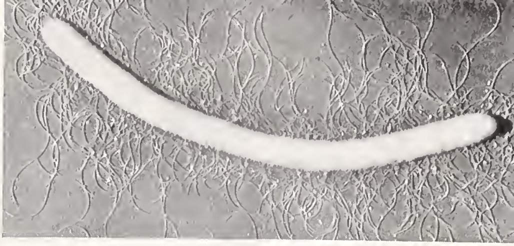
Discovery of the causes of some diseases. As you will recall from Unit 1, the causes of many diseases have been discovered by carefully controlled experimentation. Even though there had been many explanations regarding the causes of diseases, some scientists doubted them; they wanted facts which could be proved by experimentation. Among these early scientists were Pasteur and Koch. Pasteur proved that a certain *organism* (a name given to any living thing) caused a silkworm disease. Koch discovered the organism causing anthrax, a disease which had been killing many livestock as well as some people. The organisms causing these diseases were so small that a microscope had to be used to see them; thus they are often called disease-producing *microorganisms.* They are also commonly called disease *germs.*

After it was proved that anthrax and the silkworm disease were caused by germs, scientists began to suspect that other diseases, especially some of those afflicting man, might also be caused by germs. Although a number of diseases were found to be caused by microorganisms, some have other causes. We have already seen that an improper diet may cause some. Later we shall see that diseases of a different kind may occur when organs of the body fail to function properly.

DISEASE-PRODUCING ORGANISMS

How germs cause disease. Certain one-celled plant organisms, called bacteria, have been found responsible for diphtheria, typhoid fever, some kinds of pneumonia, tuberculosis, boils, one type of dysentery, and undulant fever. Some of these act by destroying tissue: in tuberculosis it may be lung tissue, in boils and abscesses the skin and muscle tissue. Others, such as the organism causing diphtheria, produce poisons called toxins, which cause illness.

Another type of plant organism, a *fungus,* causes athlete's foot and ringworm by destroying skin cells and releasing a substance that irritates the skin. Tiny animal organisms called *protozoa* may destroy red blood cells and produce a poison, causing such diseases as malaria. Other protozoa cause sleeping sickness, and a second type of dysentery. Some disease producers, *viruses,* are too small to be seen with an ordinary microscope. For this reason they were not discovered by scientists for a long time. They are so small they can pass through the membranes of body cells, and, unlike many other germs, they cannot grow outside of living cells. Very recently by using an *electron microscope,* pictures have been made of some of the viruses. Measles, mumps, fever blisters, chicken pox, smallpox, rabies, the common cold, influenza, and infantile paralysis are some common diseases caused by viruses.



J. Hillier & C. F. Robinson, SCIENTIFIC MONTHLY

Photograph of a common bacterium, enlarged 15,000 times with the electron microscope.

Other animals and plants that harm the body. Not all living organisms causing disease are microorganisms. There are a number of worms that live on the human body as *parasites.* A parasite is any organism entirely dependent on another organism. Common worm parasites such as tapeworms and hookworms enter the body as shown on page 338. They attach themselves to the lining of the intestine and damage the delicate tissues there as well as those of the lungs and muscles. Pork worm or Trichinella, another such parasite, buries itself in muscle tissue and interferes with the functioning of the muscles.

Some animals, such as certain snakes and spiders, inject a poisonous substance into the human body when they bite it. It is difficult to imagine that flowers cause illness; yet their pollen may produce a condition in some people causing hay fever and asthma. Certain poisonous mushrooms and plants cause serious illness when they are eaten. Other plants like poison ivy, poison oak, and poison sumac contain oily substances that poison when they touch the skin.

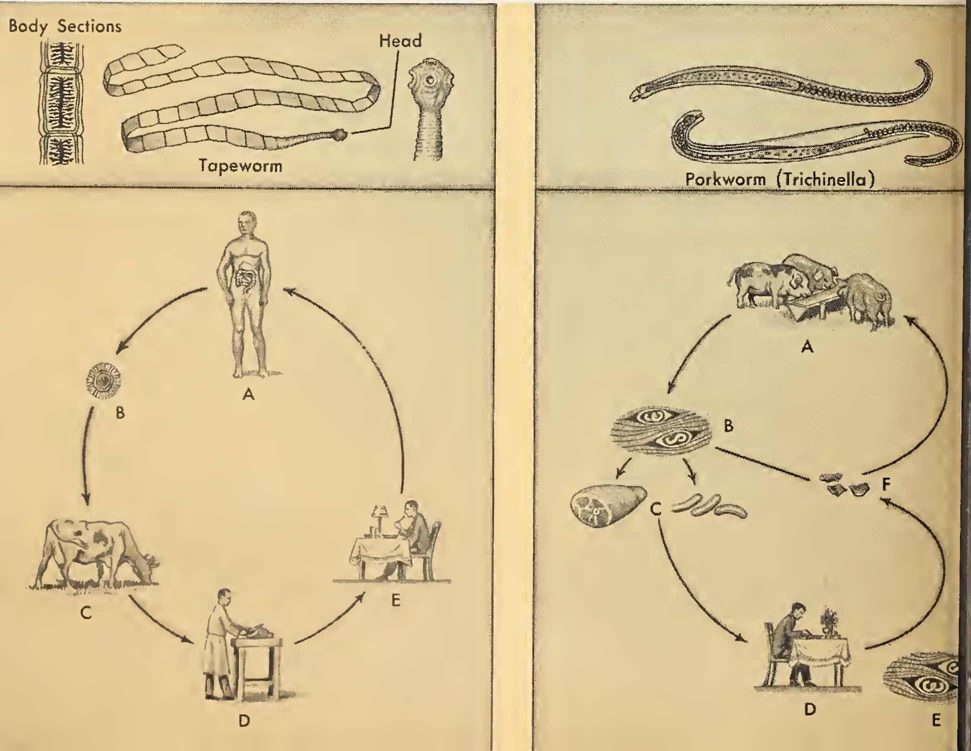
OTHER KINDS OF DISEASE

Diseases not caused by living things. Although many human diseases have been found to be caused by living organisms, some diseases have other causes. A lack of vitamins in the diet, as we have seen in the table on page 326, causes *deficiency diseases. Rickets,* night blindness, *pellagra, scurvy,* and *beriberi* are examples of such diseases. In rickets the bones become soft. Rough skin and sore mouth are some effects of pellagra, whereas sores on the body and bleeding gums are some signs of scurvy. Beriberi is a nervous disease.

An improper functioning of certain tissues or organs of the body may also cause different kinds of illness. When

Tapeworm eggs, B, passed from the intestines of an infected person, A, are eaten with grass by cattle, C. Their meat, D, containing worm cysts, infects other persons, E, who eat it. Porkworm cysts in meat of hogs, B, may infect (E) persons, D, who eat improperly cooked pork, C. Other hogs may become infected by eating meat scraps, F.

U. S. Department of Agriculture



the pancreas gland cannot produce enough of the hormone insulin, the body does not use sugar properly and a disease known as *diabetes* occurs. One of the causes of *anemia* is the failure of the spongy part of bones, called *bone marrow,* to produce sufficient red blood corpuscles. When changes take place in the lining of the stomach or small intestine so that parts of it are worn away, *ulcers* develop. Muscles of the heart or arteries may fail to function properly, resulting in disease of the circulatory system. *Cancer* occurs when a group of cells begins to multiply very rapidly. As they multiply, they grow into surrounding tissue, preventing it from functioning properly. Why groups of cells should begin growing in this manner is not yet understood.

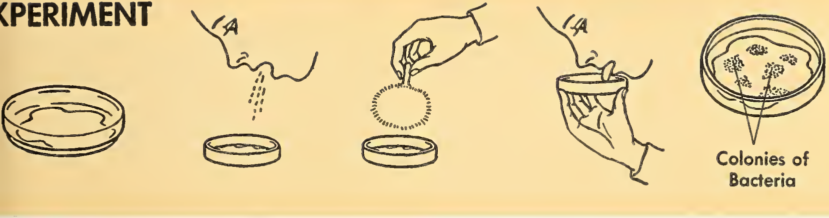
It is possible to avoid some illnesses and cure others, as you shall see in the next problems.

SUMMARY

For many thousands of years man has been attempting to explain the causes for his illnesses. Only recently has he been successful in determining by scientific experimentation the causes of many diseases.

Living organisms which enter the body may cause disease by producing toxins or destroying tissues. Some living organisms also produce substances which act as poisons when introduced into the body. Other causes of illness may be a lack of essential nutrients in the diet or a failure of tissues and organs of the body to function properly.

XPERIMENT



Question to be answered. How can the presence of bacteria be determined?

What you need. Six sterile petri dishes containing nutrient agar which is a food upon which most micro-organisms will grow. Gummed labels.

What to do. Remove the cover from each of five petri dishes, expose in the following manner, and put a label on the cover of each to show how it was exposed:

1. Cough into one dish.
2. Leave the second exposed to air in the room.
3. Shake a powder puff over the third.
4. Shake the hair over the fourth.

5. Touch the fifth with the tip of the tongue.

Replace the covers on the five dishes and seal with tape. Place all six dishes in a warm dark place for several days. Be sure to label the sixth dish which did not have its cover removed as your control.

Your answer. A colony of bacteria is made up of thousands of individual bacteria that have been reproduced from one bacterium. When colonies form, it is evidence that a bacterial cell was on the nutrient agar. How many colonies do you find on each dish? Which one had most bacteria in it to begin with? How does your control differ from the others? Why do you consider this to be a dependable way to determine the presence of bacteria? If additional dishes can be obtained it would be well to repeat this experiment several times and compare results.

Some basic assumptions in this experiment. 1. All colonies were bacterial colonies.

2. All bacteria will grow on nutrient agar.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words on your answer sheet which should be substituted for the italicized ones to make the statement true.

1. Ancient man believed that diseases were caused by *microorganisms.*
2. Athlete's foot is caused by a *fungus.*
3. Very tiny disease-producers which cannot grow outside of living cells are called *viruses.*
4. Any organism entirely dependent upon another organism is called a *toxin.*
5. Some diseases are caused by an *improper diet.*

PROBLEM 2. How does the body protect itself from harmful organisms?

OUTER DEFENSES OF THE BODY

We live in a world where it is impossible to escape from harmful organisms. If the body were not able to protect itself, these organisms would soon destroy every one of us. The fact that there are over two billion people on the earth today would indicate that the body possesses some kind of effective protection. How do these protectors operate?

Outer covering and inner lining. Look at the diagram of the skin on page 317. Note the compact hard layer of dead cell material that forms the outer layer of the skin. This prevents most harmful bacteria and other small particles from getting into the more delicate tissues underneath.

The mouth, nose, throat, esophagus, stomach, and intestines are also lined with a thin tissue called the *mucous membrane*. In the nose and throat this gives off a sticky substance called *mucus,* to which stick many small particles of material, including bacteria, normally entering the body with the air that is breathed. The bacteria-laden mucus may then be removed when you blow your nose or cough. The large intestine normally contains many millions of bacteria but the mucous membrane lining of the intestine prevents them from entering the blood and body tissues.

Protection by body fluids. Tear glands, located in the eye socket above the eyeball, give off tears that pick up bacteria and other particles that may get into the eye. The tears then drain from the eye through tubes that empty into the nose, thus washing away the particles.

You will recall that tiny glands in the lining of the stomach give off juices containing hydrochloric acid during digestion. Although the amount of hydrochloric acid present in the stomach at one time is very small, it is enough to destroy many bacteria that enter the stomach.

After the protective covering is broken. If the protective covering of the body is broken, harmful organisms may enter the body tissue. When this occurs, the tissue is said to be *infected*. Infections occurring through skin wounds, such as scratches, cuts, blisters, burns, or insect bites, are rather common. Less common is infection in the intestines caused when parasitic worms attached to the lining of the intestines break open the mucous membrane.

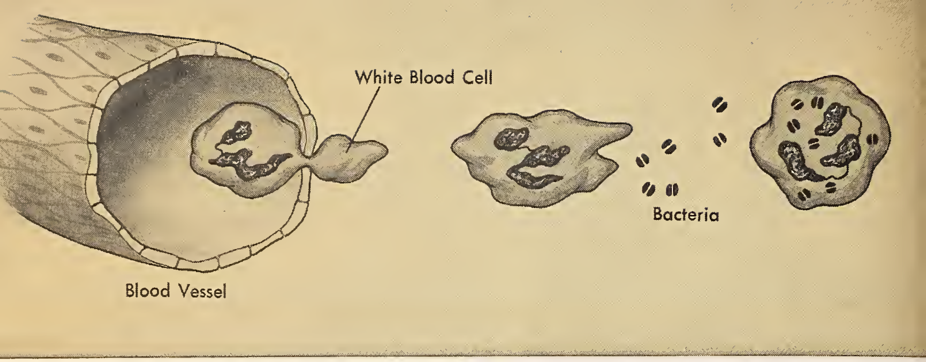
The seriousness of a ruptured appendix is known to most people. As you can see on page 311, the appendix is a small extension of the large intestine. It is also lined with mucous membrane. For reasons not entirely understood, the lining of the appendix may become infected. If the appendix is not removed or the infection checked, a break may occur through the wall of the appendix. Bacteria and the poisons formed in the appendix are then released into the body cavity. When this happened, it used to be very difficult to control the spread of infection throughout the body cavity.

INTERNAL BODY DEFENSES

White blood corpuscles. Whenever an infection occurs in the body, internal protectors take up the task of defending it. You have probably cut or scratched a finger and observed that the skin around the wound became red

One type of bacteria seen through a microscope which enlarges them thousands of times.

Hillier, Mudd, Smith, JOURNAL OF BACTERIOLOGY



White blood cells can squeeze through the microscopic openings between cells of blood vessels into fluids surrounding body cells. If bacteria are present, the white cells engulf them, as shown above.

or *inflamed* and that later pus formed within the wound. Inflammation indicated that a greater supply of blood was being furnished the wounded area. Fluids from the blood entered the wounded region and formed a thick pus containing the invading bacteria and dead blood cells. Surrounding cells formed a tissue around the pus which helped prevent the infection from spreading to other parts of the body.

In addition to red corpuscles, the blood also contains many millions of tiny white cells, called *white corpuscles,* which are extremely small and have an irregular shape (see above). They can squeeze through very tiny openings in the walls of blood vessels and move into an infected area of the body. Here they actually consume the harmful organisms.

Other cells. Special cells located in blood and lymph vessels also destroy harmful organisms much as white corpuscles do. Large numbers of these cells are found in the blood vessels of the liver. As blood passes through the liver, some of the germs that may have entered the blood are removed. When lymph passes through lymph vessels, such as those located in the neck or in the armpit, germs in the lymph are also removed.

When germs get into body tissues, cells of the body may produce chemical substances known as *antibodies.* One kind of antibody, *antitoxin,* makes harmless the toxins produced by invading organisms. Other antibodies destroy certain organisms or make it easier for white blood corpuscles to consume them. Whenever a person has recovered from diseases such as diphtheria, scarlet fever, typhoid fever, and smallpox, enough antibodies have been produced to protect him from the harmful effects of the disease. He is then said to be *immune* to the disease. His protection, or *immunity,* may last for only a short time, as in the case of the common cold, or it may last for the rest of his life, as is often true when one has recovered from smallpox.

SUMMARY

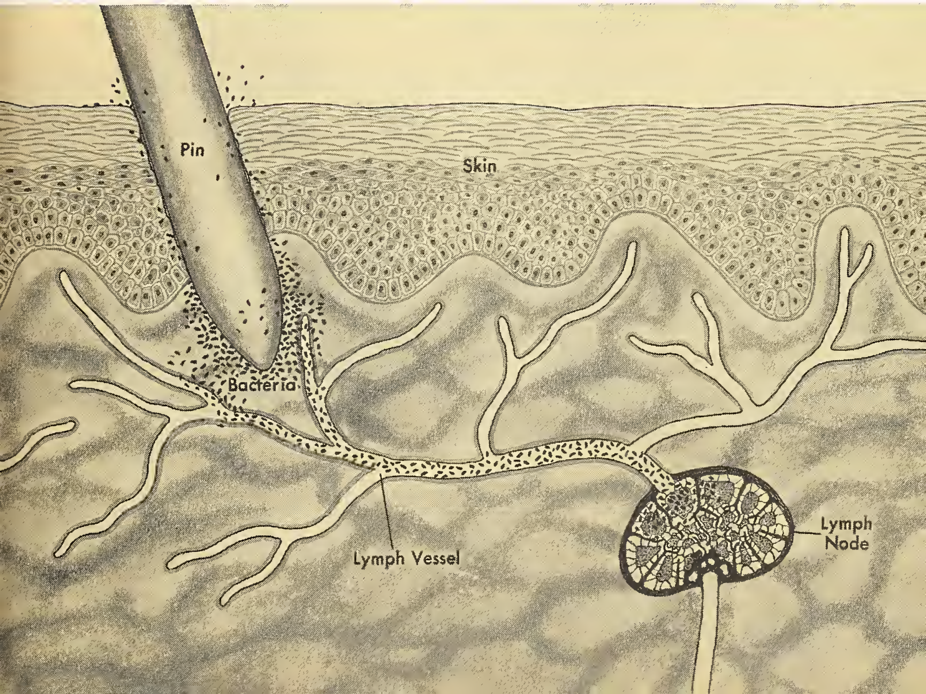
External coverings and fluids help protect the body from harmful organisms by obstructing their entrance into tissues within the body. If organisms should break through this first line of defense, other protectors set up internal defenses. These consist of (1) fluids from the blood which aid in holding the invaders together; (2) cells which form protective tissues around the infection; (3) cells which destroy the invading organisms; and (4) chemical substances which neutralize the toxins produced by the invaders. One becomes immune to a disease whenever these internal protectors have been formed which prevent the disease-producing organism from causing illness.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Many bacteria are prevented from entering the body by (a) the skin; (b) white corpuscles; (c) antibodies; (d) blood.
2. Infection in the body is caused by (a) white corpuscles; (b) antibodies; (c) harmful organisms in the tissue; (d) an over-supply of blood in the tissue.
3. Immunity to a disease is a result of (a) white corpuscles; (b) red corpuscles; (c) antibodies; (d) toxins.
4. Inflammation around a wound indicates that the wound is (a) immune; (b) free of harmful germs; (c) of no consequence; (d) infected.
5. Some germs that may be in the blood are removed by special cells as the blood passes through the (a) liver; (b) lungs; (c) lymph vessels; (d) intestines.

Whenever the skin is broken, allowing harmful bacteria to enter underlying tissues, many of the bacteria are collected in lymph vessels and passed to lymph nodes where special cells destroy them.



PROBLEM 3. How can we aid the internal defense of the body?

IMMUNIZATION

By helping the body to produce antibodies, it is possible to immunize it to some diseases. One way to do this is to inject into the body the dead or weakened disease-producing germs. These germs cause the body to produce antibodies without the person becoming ill with the disease.

Over one hundred years ago, an English physician, Edward Jenner, discovered that persons who had recovered from cowpox were immune to smallpox. He then wondered if it would be possible to immunize persons to smallpox by injecting them with pus from the sores of cows suffering with cowpox. Being a scientist, Jenner knew that the only way he could answer this question was actually to try it. He found that persons so treated became immune to smallpox.

Vaccines. Today it is believed by some that the virus causing smallpox in humans also causes cowpox in cows. But the virus is weakened after being in the cow's body. When it is introduced into human beings, it does not cause them to develop the disease, although antibodies for the smallpox virus are produced. Putting weakened or dead organisms into the body to develop immunity is called *vaccination;* the material put into the body is called *vaccine*. Today smallpox vaccine is produced in great quantities, and is widely used.

A vaccine used in immunizing people to typhoid fever is produced by killing the typhoid bacteria by heat. A small amount of this typhoid vaccine is injected into the body at first. After the body has built up some typhoid antibodies, a second larger injection is given. The second injection is followed by a third, which generally results in immunity. Injections or "booster shots" of the vaccine are given periodically in order to maintain immunity.

For some time scientists had been working on a vaccine for polio. In 1955 one developed by Dr. Salk was judged by many scientists to have great promise in protecting young people from polio.

Antitoxins. Horses are used in producing diphtheria antitoxin. The toxin produced by diphtheria organisms is weakened when it is treated with chemicals. It is then periodically injected into horses which have a high resistance to the disease. The amount of toxin is increased with each injection, and before long the horse's blood contains a large amount of diphtheria antitoxin.

During 1954 thousands of children took part in an important experiment to test Salk's polio vaccine. Dr. Salk is shown vaccinating a little girl.

National Foundation for Infantile Paralysis

HUMAN DISEASES LARGELY CONTROLLED BY IMMUNIZATION

DISEASE	TYPE OF AGENT CAUSING IT	METHOD OF IMMUNIZING
Diphtheria	Bacterium	Toxoid and antitoxin effective in most cases
Tetanus	Bacterium	Toxoid 100% effective
Typhoid	Bacterium	Vaccine
Whooping Cough	Bacterium	Immune serum
Rocky Mountain Spotted Fever	Rickettsia[1]	Vaccine
Epidemic Typhus	Rickettsia	Vaccine
Influenza	Virus	Vaccine
Smallpox	Virus	Vaccine
Rabies	Virus	Vaccine
Yellow Fever	Virus	Vaccine

[1] Organisms having characteristics similar to both bacteria and viruses.

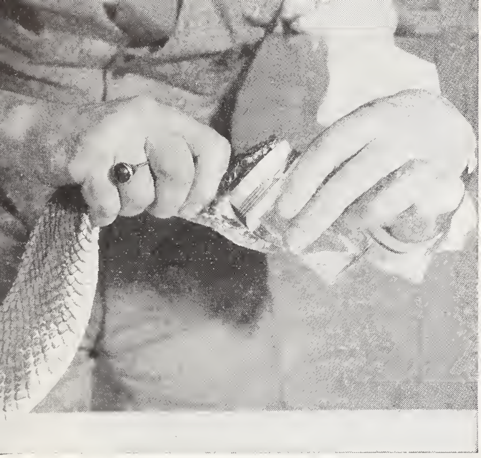
Blood is then taken from the horse, and the liquid portion of it containing the antitoxin is separated from the rest. This liquid portion is called *serum.* After the serum has been carefully tested for strength of antitoxin, it can be injected into persons suffering from diphtheria to help their bodies fight the disease. Serum containing antitoxin does not make the person immune.

In order for a person to become immune to diphtheria, his own body must produce antitoxins. To help in this process, weakened toxins, called *toxoids,* are injected into the body. At first a very small amount of the toxoid is injected, later followed by a second and then a third, larger, injection. By this treatment sufficient antibodies are built up to protect a person from diphtheria for some time.

The diseases to which people can be immunized effectively, together with the methods for immunizing them, are listed in the table above. You will note that many common diseases are not included in this table. Among those to which people cannot be immunized successfully are mumps, tuberculosis, and common colds.

Control of diseases by immunization. Immunization has greatly decreased the number of people who suffer from certain diseases. Smallpox used to be one of the most dreaded diseases. Today a case of smallpox is quite rare. *Epidemics,* or widespread outbreaks, of typhoid fever also used to be common, especially after floods and other disasters which caused food and water supplies to become contaminated with typhoid germs. Whenever there is a possibility of such an outbreak today, people are immunized against typhoid, and the disastrous results of the disease are avoided. Diphtheria, once common, has become almost unknown since the practice of immunizing children began.

Tests to determine immunity. Tests have been developed which make it possible to determine whether an individual is immune to some diseases. In the *Schick test,* used in determining the immunity of an individual to diphtheria, a very small amount of diphtheria toxin is injected under the skin. If a red spot appears, it is likely that the individual is not immune to diphtheria. Similar tests have been developed for typhoid fever and scarlet fever.



New York Zoological Society Photo

A scientist "milks" a rattlesnake to obtain the venom which is needed to produce antitoxin, the material inoculated into people bitten by snakes.

INOCULATIONS AND CHEMICALS

Protection from poisons of snakes. *Inoculation,* or the injection of substances into the body, may be used to help the body counteract poisons from the bites of snakes and spiders. Rattlesnake poison or *venom* is obtained from rattlesnakes and injected into another animal, whose body produces antitoxin to counteract the poison. Blood serum from this animal, containing the antitoxin, is used to inoculate persons who have been bitten by rattlesnakes.

Inoculations for hay fever. Many hayfever victims have been relieved by inoculations. As you will recall, some people suffer from hay fever because their bodies are highly sensitive to certain plant pollens. Tests can be given to these patients to determine the plant pollens to which they are sensitive. Early in the spring a series of injections containing the offending pollens are begun and continued throughout the summer. By summer the patient's body has developed a resistance to the pollens that have previously caused him so much misery. It should be pointed out that hay-fever patients differ in the extent to which they can develop resistance to pollens by inoculations. Some respond to this kind of treatment, whereas others do not.

Chemicals that aid the body protectors. For many years scientists tried to find chemicals which could be used to control harmful organisms in the body and yet not harm cells of the body. Their search has been successful; a number of chemicals have been discovered that can be used in this manner. *Quinine* and *atabrine* are used to check the development of the organisms causing malaria. Several different kinds of sulfa drugs are used in the treatment of diseases caused by certain bacteria and viruses. Penicillin, *streptomycin, aureomycin,* and *chloromycetin,* chemical substances obtained from molds and called antibiotics, have been used with great success in treating many different kinds of diseases caused by bacteria and viruses. The use of chemicals, such as sulfa drugs and penicillin, in treating diseases is called *chemotherapy.*

SUMMARY

The internal defense of the body against harmful organisms can be aided by increasing the amount of antibodies and by using chemicals to destroy or check the development of disease-producing germs after they have entered the body. Antibodies may be increased by (1) injecting them into the body from some other source; (2) introducing weakened toxins; or (3) introducing dead or weakened disease organisms into the body. Only those chemicals which will check the development of disease-producing germs without harming body cells can be used in chemotherapy.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Putting weakened or dead organisms into the body to develop immunity is called (a) inoculation; (b) vaccination; (c) chemotherapy; (d) inflammation.
2. Widespread outbreaks of diseases are known as (a) epidemics; (b) toxoids; (c) vaccination; (d) immunizations.
3. Immunization against diphtheria is produced by injecting into the body (a) weakened diphtheria organisms; (b) chemically weakened toxins; (c) antitoxins; (d) vaccines.
4. The Schick test is used in determining immunity to (a) smallpox; (b) scarlet fever; (c) mumps; (d) diphtheria.
5. The use of chemicals in treating diseases is known as (a) immunization; (b) inoculation; (c) chemotherapy; (d) vaccination.

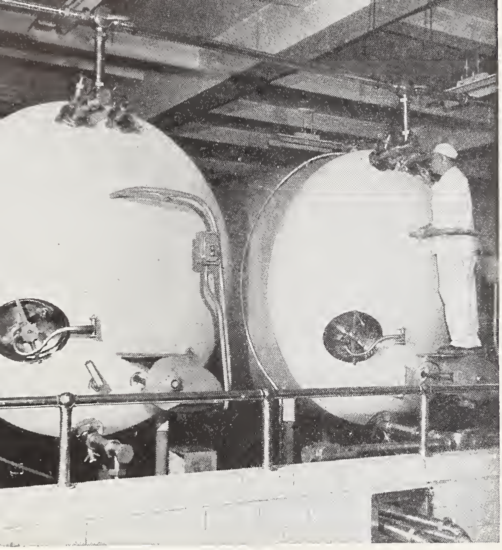
PROBLEM 4. How can harmful organisms be prevented from entering the body?

CONTROL OF HARMFUL ORGANISMS

Disease-producing organisms are spread in many different ways. Whenever a person with a cold coughs or sneezes without properly covering his mouth, a fine spray of moisture is discharged into the air. Each droplet of the moisture may carry some cold-producing organisms, which persons in the vicinity may inhale. Disease-producing organisms may get into the body by being carried to the mouth on unclean hands. Foods such as milk handled by diseased persons or processed under unclean conditions may become contaminated with typhoid fever and tuberculosis germs. The organisms causing dysentery may be transferred to the body when unclean raw vegetables are eaten. Tapeworms and pork worms may be transferred to the body when improperly cooked meat is eaten. Malaria germs, found only in the body of a person suffering from malaria, can be transferred to another person by a particular type of mosquito that has bitten the infected person.

Pasteurization of milk. Milk is heated to destroy disease-producing microorganisms that might be in it. It may be heated to a temperature from 142° F to 145° F and held there for thirty minutes, or it may be heated to 160° F for a much shorter period of time. This process is called *pasteurization* and is required by law in most places before milk can be sold. Pasteurized milk may become unsafe again if it is not protected from contamination after it is pasteurized.

Proper sewage disposal. Since many harmful organisms are eliminated from the body in human wastes, it is vital



The Borden Company

Raw milk is stored in holding tanks like these at low temperatures. Next it is pasteurized by being heated to 162° F., for 16 seconds, to kill all harmful bacteria. It is then quickly cooled before bottling.

that provision be made for safe disposal of sewage. Several methods for disposal of sewage were described in Unit 2.

Control of small animals. Flies may carry disease germs to humans. The places where flies and other insects produce their young are called *breeding* places. Garbage and other filth are common breeding places. If flies are to be controlled, therefore, garbage must be collected and properly treated, streets kept clean, and houses screened to keep out the flies. Many different methods of disposing of garbage have been tried, but the most effective method is to burn it. Today many cities burn their garbage in large *incinerators.*

Mosquitoes also can be controlled by destroying their breeding places. Mosquitoes lay their eggs in water. The eggs hatch into worm-like organisms called *larvae,* which then develop into adult mosquitoes. Swamps, puddles, or any open vessel of water may become a breeding place for them. Therefore, whenever practical, swamps should be drained and tin cans, barrels, and other containers removed or kept covered so that they will not collect water. Whenever it is not practical to drain swamps or puddles of water, they should be sprayed with oil. The oil forms a thin film over the water and kills the mosquito larvae by making it impossible for them to get air.

In order to control the disease called bubonic plague, rats must be destroyed, for they can become infected with the germ causing bubonic plague. Fleas may bite infected rats and then transfer the germs to humans. Proper disposal of garbage and ratproofing of buildings where rats might obtain food are the most effective ways of controlling them.

The germ causing typhus fever is carried from one person to another by body lice, which live on dirty clothing and on the bodies of people who do not keep themselves clean. During World War II, it was not always possible for soldiers at the front to keep their bodies and clothing clean. In order to destroy body lice, soldiers dusted their bodies regularly with a powder containing a chemical, called *DDT.*

A number of poisons are used in killing insects that carry disease germs. Today it is possible to obtain small bombs which produce a fine mist of a liquid poisonous to insects.

Disinfectants. Many different methods are used to kill disease-producing organisms that may be on articles or objects where they could infect man. For instance, bedding and various articles that have been used by persons suffering from a germ disease should be disinfected. Anything that might be used to kill microorganisms and make them harmless is called a *disinfectant*. A number of different chemicals are used as disinfectants, in addition to the ultraviolet radiations discussed in Units 2 and 4. Heating objects to high temperatures is one of the best ways to disinfect them.

Chemicals may be used as disinfectants in several ways. They may be dissolved in water and the solution used to wash or scrub the article to be disinfected. They may be used in the form of a gas or vapor to disinfect a room or building, a process sometimes called *fumigation.*

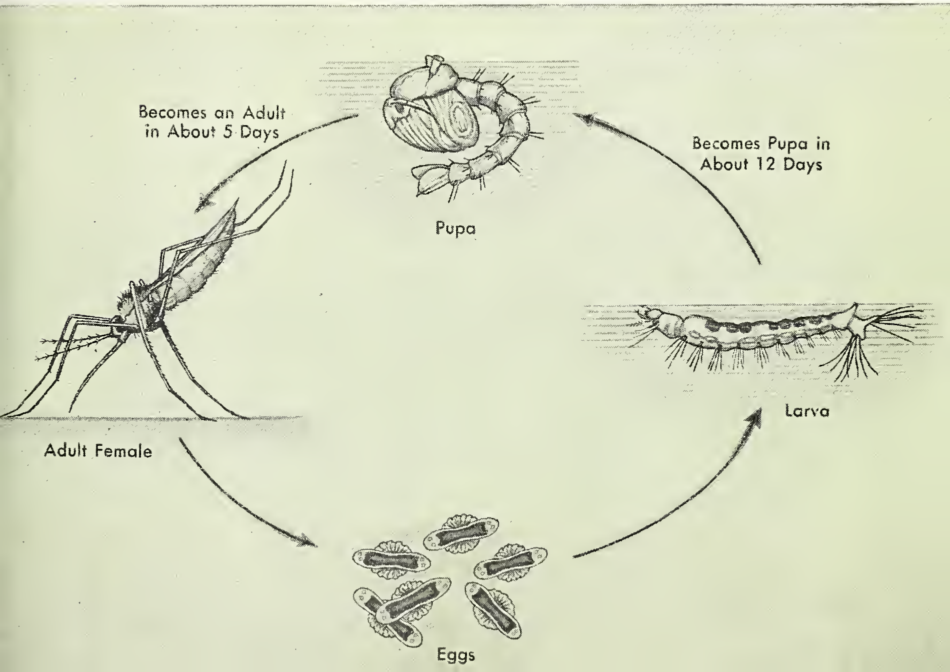
Boiling and steaming are effective methods of using heat as a disinfectant. The length of time that articles should be treated will depend upon the type of organism that is to be killed, because it takes longer to kill some germs with heat than others.

Isolation of infected persons. Diseases that spread directly from one person to another are called *contagious* diseases. To prevent their spread, persons who are ill with them should be kept away from anyone who is not immune. This practice is called *isolation* or *quarantine*.

Purification of water. The water supply must be carefully guarded to prevent people from becoming infected with harmful organisms. Some of the methods commonly used in purifying water were described in Unit 2.

Departments of public health. The prevention of contagious diseases is one

The life cycle of the mosquito. The female lays her eggs in water, and under favorable conditions the eggs will hatch into larvae in about four days. Each larva then becomes a pupa and after about five days of further development the pupa becomes an adult mosquito. Many insects go through these same stages in their development from eggs to adults.


Becomes an Adult in About 5 Days
Pupa
Becomes Pupa in About 12 Days
Adult Female
Larva
Eggs

of the important functions of city, county, and state departments of public health. Workers in departments of health keep records of all cases of contagious diseases. By locating and controlling sources of contagious diseases, they can prevent epidemics.

Representatives from the department of health inspect food sources frequently. In some cities food handlers are examined periodically to determine whether they are carrying disease germs. Since so many diseases are transmitted through unclean milk, dairies are inspected regularly to make sure that the milk is clean. Drinking water as well as water in swimming pools and at bathing beaches is tested periodically to determine whether it is safe for human use.

SUMMARY

Harmful organisms may enter the body through air, food, or water, or by contact with contaminated objects. To prevent harmful organisms from entering the body (1) they may be killed before they enter the body; (2) material in which they may develop can be destroyed; and (3) small animals such as insects that carry the organisms can be controlled. The maintenance of a department of health is one way in which the citizens of a community cooperate in protecting themselves from disease.

EXPERIMENT

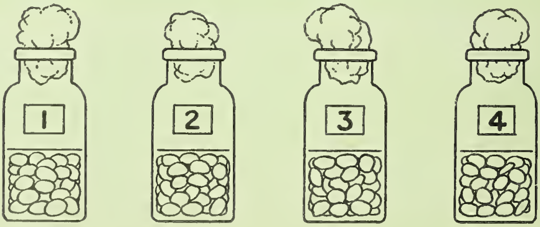
Question to be answered. Do flies carry bacteria?

Materials needed. Several live flies in addition to the materials used in the experiment on page 339.

What to do. Plan your experiment following the procedure used in the experiment on page 339.

Your answer. From your evidence how would you answer the above question? What were your assumptions?

EXPERIMENT



Question to be answered. How do three different disinfectants compare in their control of microorganisms?

What you need. Four bottles, a cup of dry beans, solutions of equal concentration of three different disinfectants of your own selection, sterile absorbent cotton, water.

What to do. Soak the cup of beans in water for several hours. Put the same amount of beans in each of the four bottles. Cover seeds in bottle No. 1 with boiled water after it has been cooled. Cover the beans in each of the other bottles with a solution of one of the disinfectants. Stopper all bottles with sterile absorbent cotton and put in a warm place. After several days remove the plug from each bottle and smell the contents.

Your answer. From which bottles was there an odor? What caused it? Based upon this test how would you judge the three different disinfectants?

Assumptions in this experiment. 1. Unpleasant odors are an indication of the presence of microorganisms.

2. The microorganisms in these jars are similar to those which these disinfectants are supposed to control.

TEST YOURSELF

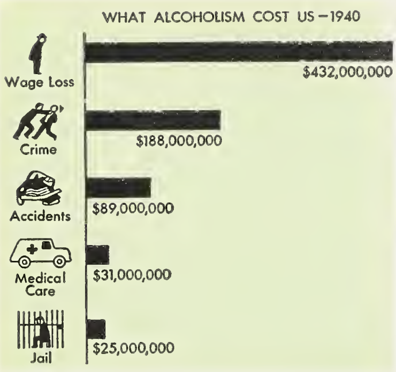
If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words on your answer sheet which should be substituted for the italicized ones to make the statement true.

1. The most effective method of controlling mosquitoes is to *kill the adult mosquitoes.*
2. Proper sewage disposal *is important* in controlling disease.
3. Anything which may be used to kill microorganisms or make them harmless is known as a *disinfectant.*
4. The practice of keeping people ill with contagious diseases away from other people is *fumigation.*
5. Workers in public health departments are primarily concerned with *prevention* of disease.

PROBLEM 5. How does the use of alcohol, tobacco, and narcotic drugs affect the body?

You no doubt have heard many times that drinking and smoking harm the body, and yet you have also observed that a number of people may not appear to be harmed by the use of alcohol and tobacco. Since there seems to be conflicting evidence regarding the effects of alcohol and tobacco, it is important to determine the facts. There is no question about the harmful effects of narcotics, as you shall see in your study of this problem.

Alcoholic beverages. The alcohol found in alcoholic beverages is *ethyl* alcohol produced by the action of microorganisms upon sugar. Wines are manufactured by allowing yeast to act upon the sugar in fruit juices, thus changing some of it to alcohol. Beer and whiskey are manufactured by changing the starch in certain grains, such as rye and barley, to sugar and then allowing microorganisms to produce alcohol from the sugar. Wines contain about 14 per cent alcohol, and beer about 6 per cent, and the stronger liquors 40 to 50 per cent.



Alcohol as a food. There has been much discussion as to whether alcohol could be considered a food. Since alcohol cannot be used to build body tissue nor to regulate essential body processes, it lacks two essential characteristics of food. Although it can be used to produce energy in the body, it has other effects upon the body which make it an undesirable source of energy.

Effects of alcohol upon the nervous system. The nervous system, especially the brain, is affected by alcohol. A talkative person who has been drinking may give the impression that he is more alert after a few drinks, but he is not. The alcohol has affected parts of his nervous system which control thought and speech so that he talks with little consideration for what he is saying. The serious and important matters about which he should be concerned do not bother him so much when he is under the influence of alcohol. Because of this, some people begin using alcohol as a means of forgetting their worries. Others may use it at parties or other social gatherings because they believe it helps them enjoy such gatherings.

A number of tests have been performed to determine the effects of alcohol upon the speed with which a person acts. Results of these tests have proved that a person who has been drinking acts more slowly and less accurately. For these reasons it is dangerous for anyone who has been drinking to drive an automobile or perform other kinds of activities involving the safety of human life.

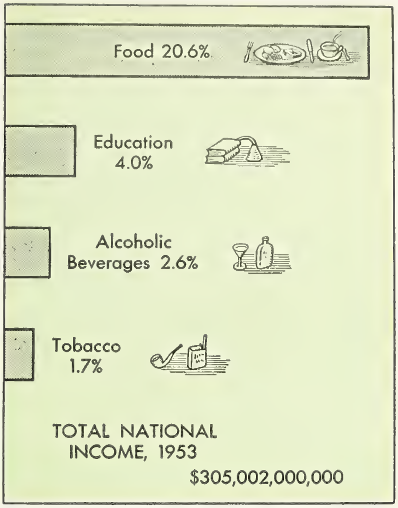
The habitual use of alcohol. Some people may drink small amounts of alcoholic beverages occasionally without feeling that they have to drink regularly. Others, once they have developed the habit of drinking, find it difficult to quit. These people are called habitual drinkers. Some of them use alcoholic beverages regularly but in moderate amounts, whereas others find it necessary to drink increasingly large amounts. There is one group of drinkers who, after taking one drink, are unable to stop. This type of drinker is generally referred to as an *alcoholic*. An alcoholic may consume so much alcohol that death results.

Alcoholism. Alcoholics cannot live normally. They soon lose their positions and become dependent upon relatives or social institutions for their care. It has been estimated that there are about three quarters of a million alcoholics in the United States.

Health and long life. Insurance companies have studied the effects of drinking upon the number of years a person may live. They have found that excessive or heavy drinking shortens one's life. Heavy drinking seems definitely to interfere with mental activity, reduces resistance to infection, and lowers the general health of the individual.

USE OF TOBACCO

The effects of tobacco. No one has found smoking to be necessary for proper functioning of the body. Smoke from tobacco contains a number of substances, including nicotine, which may produce harmful effects in the body. In many studies, it has been found that smoking frequently causes an irritation of the throat, leading to coughing and burning sensations. There is some evidence that smoking, especially cigarettes, may cause lung cancer. Some studies have found that smoking may result in loss of weight and tendency to take colds. Various stomach disorders have been attributed to smoking, although the evidence here is not conclusive. In some cases, smoking causes a loss in appetite and shortness of breath. The experience of many athletic coaches indicates that a person can be a better athlete if he does not smoke.



Why people smoke. Reasons why people develop the smoking habit are not clearly understood. It has been shown, though, that once a person begins smoking, he generally develops the habit and may find it difficult to quit. Smokers give many reasons for continuing to smoke. They say that they like the fragrance of the smoke or that smoking quiets their nerves and rests them. Still others may claim that smoking gives them a "lift" or stimulates them. There is no evidence to support the claims that smoking is essential for relaxation or for stimulation.

USE OF DRUGS

Effects of narcotic drugs. Narcotic drugs include opium, morphine, codeine, heroin, and a number of other drugs which have a numbing effect upon the body. Some of these drugs have been used by doctors to relieve the pain of their patients for short periods of time. If, however, a person should continue to take them for some time, he may form the habit and believe that he cannot get along without them. The use of some of these drugs may actually cause changes in body cells, tissues, and organs which require the continued use of the drug for their functioning. When this happens, the person has become *addicted* to the drug. If a drug addict does not use the drug regularly, he suffers great physical pain and mental disturbances. Both the habitual user of drugs and the addict honestly believe that they will die or go insane if they do not get them. For this reason they feel justified in doing anything, even to committing murder, to get their drugs.

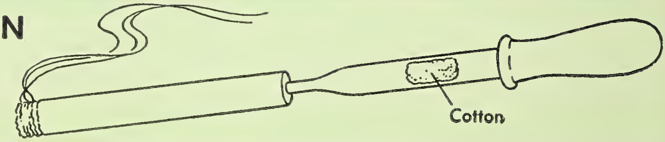
Why some people become addicts. Many older addicts got started by using drugs to relieve physical pain or to escape facing their problems. Uncontrolled curiosity and a desire to make an impression upon someone has resulted in many of the younger addicts getting their start. Most of them followed the same general pattern. First it was alcohol, then they tried marihuana, and finally heroin.

Prevention of addiction. Before 1914 there were no laws to control the use of narcotic drugs. Today, however, there are laws that limit the amount that can be produced or brought into our country. Narcotic drugs can be used only for medical purposes and their use is under very close supervision. Since they have been found to be habit-forming, certain drugs (barbiturates) commonly used in sleeping pills can now be obtained only by a physician's prescription. Although drug addiction has decreased steadily over the past 50 years, it is still a serious problem in many places.

SUMMARY

The evidence from studies regarding the effects of alcohol and tobacco upon the body leads to one conclusion. Whenever alcohol and tobacco have been found to affect the body, the effects have generally been undesirable. If one desires to maintain best physical and mental condition, he should avoid the use of alcohol and tobacco. Because of its effects upon human beings, everyone should be alert to situations that might lead to drug addiction.

OBSERVATION



What to observe. The tar from cigarette smoke.

How to observe it. Remove the rubber bulb from a medicine dropper, and insert a piece of cotton into the tube as shown. After the bulb is replaced, push the point of the dropper into the butt end of a lighted cigarette. Draw the smoke through the cotton by squeezing the bulb several times.

Interpretation of your observation. How does this show that tars are present in cigarette smoke? Nicotine in tobacco smoke is colorless, so this does not show the presence of nicotine. Would you expect to find tars in all brands of cigarettes? How could you find out?

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. A person who has been drinking alcohol (a) is more alert; (b) reacts more rapidly and accurately; (c) reacts more slowly and less accurately; (d) considers carefully what he says.
2. A drug addict is one who (a) sells narcotics; (b) takes a sleeping pill upon physician's prescription; (c) has used drugs until his body has changed; (d) is no longer affected by drugs.
3. Insurance companies have found that excessive drinking (a) lengthens life; (b) shortens life; (c) increases resistance to infection; (d) improves one's general health.
4. Smoking tobacco (a) may produce harmful effects on the body; (b) helps one become a better athlete; (c) aids the proper functioning of the body; (d) increases the appetite.

CHAPTER ACTIVITIES

REVIEW THE CAUSES OF DISEASE

1. Five general causes of disease are listed below, followed by a list of the names of a number of diseases. On your answer sheet, beside the letter of the name of the disease, write the number of the general cause responsible for it. **Do not write in your textbook.**

GENERAL CAUSES OF DISEASE

1. Bacteria
2. Protozoa
3. Viruses
4. Diet deficiency
5. Improper functioning of tissue or organ

NAMES OF DISEASES

a. Diphtheria
b. Ulcers
c. Measles
d. Sleeping sickness
e. Scurvy
f. Mumps
g. Common cold
h. Rickets
i. Diabetes
j. Rabies
k. Typhoid fever
l. Pellagra
m. Anemia
n. Smallpox
o. Malaria fever
p. Tuberculosis
q. Beriberi
r. Influenza
s. Infantile paralysis

USE A GENERALIZATION

Two important generalizations developed in this chapter are listed below. Following each is a list of statements some of which were used in forming the generalization. On your answer sheet, write the letters of those statements which were used in forming the generalization under which they are listed.

1. The body has several natural protectors against disease.
   a. The outer layer of the skin is formed from a compact hard layer of dead cell material.
   b. Some parts of the body are covered with mucous membrane.
   c. White blood corpuscles consume many harmful organisms that enter the body.
   d. Oxygen is carried by the hemoglobin in the blood.
   e. Sometimes body cells produce antibodies which make invading organisms harmless.
   f. Many of the microorganisms that cause disease are extremely small.
2. The use of both alcohol and tobacco may have harmful effects upon the body.
   a. Excessive drinking of alcohol may reduce the body's ability to resist infection.
   b. Alcohol is produced by the action of microorganisms on sugar.
   c. A person who has been drinking an alcoholic beverage cannot respond to stimuli with his usual speed and accuracy.
   d. Excessive use of alcohol may result in death.

UNIT ACTIVITIES

APPLY YOUR KNOWLEDGE

Six of the generalizations which were developed in this unit are listed below. Following them a number of statements describing activities of people are listed. In the proper place on your answer sheet, beside the letter of the activity, write the number of the generalization illustrated by each activity.

GENERALIZATIONS

1. Each of the many types of cells in the body has a special kind of work to do.
2. The cells must be furnished with sufficient food and oxygen for them to meet the energy demands of different activities, and waste materials must be removed from them.
3. The body requires a variety of nutrients if it is to operate most efficiently.
4. The body can protect itself against diseases.
5. The body can be aided in its protection against diseases.
6. Methods have been developed to help control the spread of diseases.

ACTIVITIES

a. Playing football and perspiring freely while playing
b. Exercising vigorously, causing a person to breathe more rapidly and deeply
c. Covering swamps with a film of oil
d. Taking a number of inoculations before traveling in foreign countries
e. Serving meals consisting of a variety of foods
f. Withdrawing your finger immediately after accidentally touching a hot object

g. Eating less food when working in an office than when doing heavy construction work
h. Eating some food from each of seven different food groups each day
i. Quarantining people who have certain diseases
j. Digesting food without any conscious control on your part
k. Providing more protein in the diet of a growing person than in that of an adult
l. Resting after becoming fatigued
m. Covering and storing fresh vegetables in a cool place
n. Pasteurizing milk and delivering it in sealed bottles
o. Constructing sewage disposal plants in cities
p. Inspecting restaurants for sanitary precautions

LEARN MORE ABOUT YOUR BODY

1. Keep a record of both the kind of food and the approximate amount of each kind you eat during one week. Analyze your food record to see if you are getting all the nutrients you need in sufficient amounts.

2. While breathing normally, count and record the number of breaths you take per minute. Also record the number of heartbeats per minute by counting your pulse. (This can be done by placing the tips of the fingers of the left hand against the inside of the right wrist just back of the thumb and pressing slightly.) Now hop up and down 50 times on one leg and again record the number of breaths and heartbeats per minute. How do you account for changes in your breathing and heartbeat rates?

3. Collect a number of food misconceptions from people you know. See if you can discover how the misconception started.

4. Collect a number of food advertisements. See if you can find scientific evidence to support the claims made in them.

VISIT PLACES

1. The department of health to see what is done to prevent the spread of disease

2. A food market to see what measures are taken to keep the food sanitary

3. A dairy to observe the sanitary precautions taken to keep milk from becoming contaminated

REPORT ON HEALTH TOPICS

1. Purefood and drug laws
2. Experiments which led to discovery of vitamins
3. The foods of people of other lands
4. What is being done to control diseases such as cancer, infantile paralysis, tuberculosis
5. Using blood to treat diseases
6. Laws controlling sale of narcotic drugs
7. The plagues of olden times
8. Control of such health menaces as rats, mosquitoes, and flies
9. The newer antibiotics

READ ABOUT THE HUMAN BODY

Cant, Gilbert. *Medical Research May Save Your Life.* Public Affairs Pamphlet. New York: Public Affairs Committee, 1953.

Tells how research during the past 15 years has added eight more years to our lives on the average.

Carlson, Anton J., and Johnson, Victor. *The Machinery of the Body*. Chicago: University of Chicago Press, 1953.

The answers to most questions you may have about the workings of the body can be found in this book, which has a splendid index.

Eisenberg, Philip and Miriam. *The Brave Gives Blood*. New York: Julian Messner, Inc., 1954.

Explains blood types, the make-up and role of blood as a part of a story about an Indian brave who gave blood for a transfusion which saved a boy's life.

Jordon, Edwin P. *You and Your Health*. New York: G. P. Putnam's Sons, 1954.

Many useful facts presented simply and scientifically.

Keliher, Alice V. *Life and Growth*. New York: D. Appleton-Century Company, 1941.

This book, written especially for young people, was based upon their own questions about their bodies and the changes which occur as they grow up.

Marvin, H. M. and others. *You and Your Heart*. New York: Random House, Inc., 1950.

An easy-to-read book on the heart and circulation.

Poliomyelitis—A Source Book for High School Students. New York: The National Foundation for Infantile Paralysis, Inc., 1953.

This pamphlet was written for high school youth who were concerned about a polio epidemic in their community; it will answer many of your questions.

Ravielli, Anthony. *Wonders of the Human Body*. New York: The Viking Press, Inc., 1954.

The author explains the construction of the body and how it functions. The illustrations are very good.

Riedman, Sarah R. *Food for People*. New York: Abelard-Schuman, Inc., 1954.

This book covers the chemistry of food, the processes of digestion, the importance of vitamins, fads and facts about food, and the problems of world food supply.

Riedman, Sarah R. *The World Through Your Senses*. New York: Abelard-Schuman, Inc., 1954.

How impulses travel along nerve circuits; how we feel, see, hear, smell, taste, and many more facts about the communication and control machinery of organisms are discussed in this book.

Riedman, Sarah R. *Your Blood and You*. New York: Henry Schuman, Inc., 1953.

Contains interesting material on human blood prepared especially for young people.

Selsam, M. E. *Microbes at Work*. New York: William Morrow and Company, 1953.

Fascinating book that clearly and accurately explains the many different effects and uses of the various microbes such as bacteria, molds, and yeast.

Spalding, Willard B., and Montague, John R. *Alcohol and Human Affairs*. Yonkers-on-Hudson, New York: World Book Company, 1949.

The alcohol problem as well as tobacco, narcotics, and other drugs is dealt with in a manner that is easily understood.

Yahraes, Herbert. *Your Teeth—How to Save Them*. Public Affairs Pamphlet. New York: Public Affairs Committee, Inc., 1949.

On the first page of this pamphlet, 32 questions about teeth are asked. This pamphlet will answer all of these questions.

Bureau of Plant Industry, Soils, and Agricultural Engineering

Care is given to those plants and animals that produce the things we need. This tomato plant, raised from seed in a greenhouse where it was protected from cold temperatures, is now transplanted outdoors.

unit 9 LIVING THINGS

IT would not be possible for human beings to live on this earth if there were no other living things. We are dependent upon plants and animals for the oxygen we breathe, the food we eat, and many of the materials used in making our clothes and building our homes. Animal pets, flower gardens, potted plants, green lawns, and shade trees help make our lives more enjoyable.

The natural supply of these living things is not sufficient to meet our many needs. We therefore have to help them reproduce in larger numbers. In order to do this, it is important to understand how living things reproduce.

We must provide special care for living things if they are to grow and produce what we need. Understanding how plants manufacture food and the conditions that affect their growth will help us learn better how to care for plants. In a similar manner, an understanding of the different types of animals we raise should help us take better care of them.

Man has not always been satisfied with the types of plants and animals he has raised. He has wanted bigger and better types and has found ways of obtaining them, although he has not always understood how it happened.

A study of this unit should help you understand how living things reproduce, and how it is possible to help them reproduce in larger numbers. You should also learn how to care for plants and animals so that we can have more of them for our use. Finally, you will learn how we can produce types of plants and animals that better meet our needs.

U.S.D.A. Photograph

A farmer plants turnip seeds, using seeds guaranteed to have an 80% germination standard, as shown on the package.

chapter 19 PROPAGATION OF LIVING THINGS

THE food we eat and many of the materials we use in making our clothes come from plants and animals. At one time man may have found it possible to obtain sufficient food and other materials from the plants and animals he found growing naturally on the earth. But today the natural supply of plants and animals is no longer sufficient to meet our needs. We must produce more plants and animals of many different kinds to supply us with food and other materials. For this reason, it is important to understand how plants and animals reproduce their kind and how more of them can be obtained by aiding their reproduction.

PROBLEM 1. How are plants propagated?

PROPAGATION BY SEEDS

The methods of aiding plant reproduction are called *propagation.* Plants can be propagated in a number of ways depending upon the manner in which different ones reproduce. Regardless of the way they reproduce, it is their cells which bring it about. As is true in our bodies, all parts of the plant are made up of cells. If the leaf of a water plant, called *Elodea,* is observed through a microscope, its cells will look somewhat like the drawing below.

Plant cells also contain protoplasm (see page 308) which is similar to that found in the cells of our bodies. Reproduction in plants, and all living things for that matter, depends upon the activity of the protoplasm. When the protoplasm in a one-celled plant divides, each new cell becomes a new plant. In many-celled plants, such as a tree, the production of new cells by cell division may merely result in growth of the plant. At times, however, certain cells may go through a series of cell divisions and finally produce a new plant. Let's see now how this might take place in producing seeds.

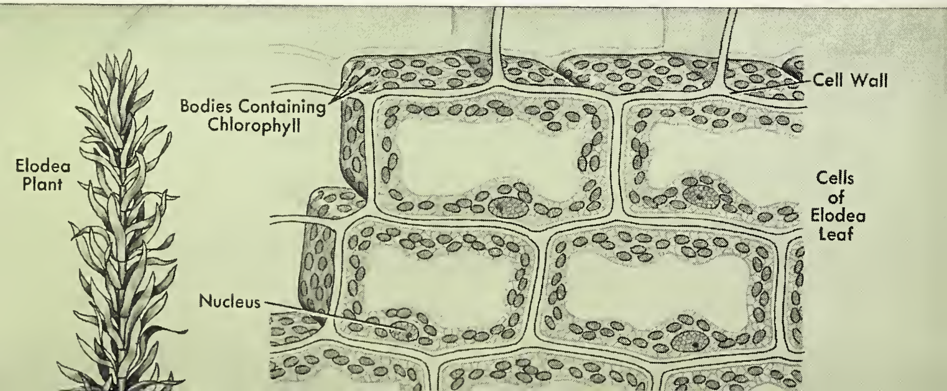
Producing seeds. If you were to cut open a bean seed, you would find stored food and, attached to one end of it, a tiny, undeveloped plant, as shown on page 364. As you probably know, seeds come from flowers.

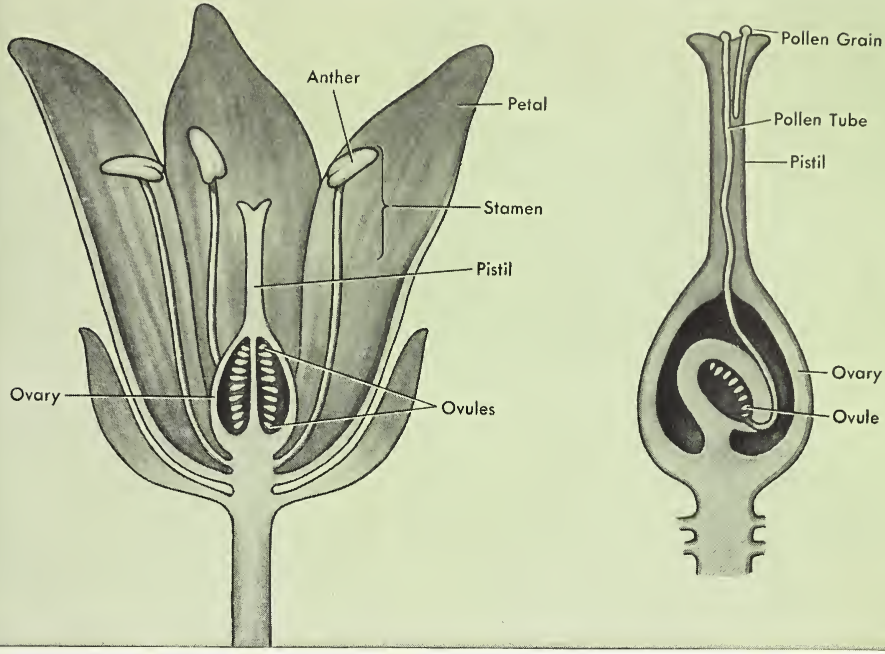
The parts of the flower necessary in producing seeds are shown on page 363. The lower part of the *pistil,* called the *ovary,* produces a small structure called the *ovule.* The ovule produces a special kind of cell known as the *egg* from which the little plant in the seed developed. However, the egg cell alone cannot produce a plant. Another kind of cell is needed.

At the top of each *stamen* is the *anther* which produces *pollen.* Pollen is made up of very small particles called pollen grains, each containing a small bit of protoplasm. Pollen grains are so small that they are easily carried in the air or by insects that alight on flowers.

Whenever a grain of pollen is carried to the upper part of this pistil, *pollination* is said to take place. If the pollen is transferred from the stamen to a pistil of the same flower, it is called *self-pollination.* If the pollen is transferred from the stamen of one flower to the

The cells of an Elodea leaf are separated from each other by a cell wall inside of which is the protoplasm. Here are found tiny green bodies, called chloroplasts, containing chlorophyll. These enable green plants to manufacture food.





On this plant the stamen and pistil, which are necessary for producing seeds, are located in the same flower. On some plants, such as corn, the stamens and pistils are located on different parts of the plant.

pistil of a different flower, *cross-pollination* occurs.

After pollination, the grains of pollen begin to grow and form long tubes extending through the pistil into the ovary. As each pollen tube grows, a tiny body, called the *sperm nucleus,* develops within the protoplasm of the tube. When the pollen tube reaches the ovule, the tube breaks and the sperm nucleus combines with another small body, the *egg nucleus,* inside the egg cell. The combining of these two nuclei is called *fertilization.* After it takes place, the egg begins to divide and forms many more cells, which grow and develop into the little plant that is found in a seed. During its early development this tiny plant is called an *embryo.* After fertilization other parts of the ovule develop at the same time into the food-storage parts of a seed. The embryo and stored food are enclosed in a protective covering called the *seed coat.* A seed, then, consists of the embryo and stored food within a seed coat. In some plants different parts of the flower develop into a fleshy *fruit* after fertilization. The seeds are a part of the fruit.

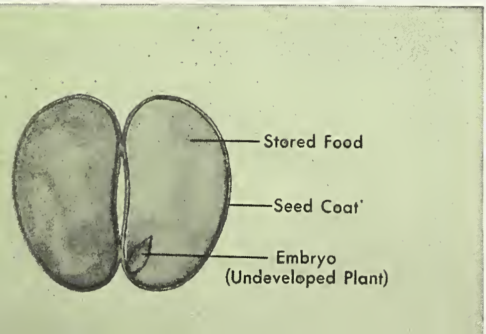
Germination tests. After a seed is formed, the small plant inside it must remain alive if the seed is to be of any value in raising plants. If the little plant remains alive, it will begin to grow when the seed is put in a moist, warm place. This early growth is called *germination.*

Most seed producers test samples of their seeds before they sell them, and usually print on the outside of seed packages the percentage of seeds that can be expected to germinate. When farmers raise their own seeds they may test them by taking samples of the seeds to be used for planting and putting them in a moist, warm place. The number of seeds that germinate is counted and the percentage of germination is determined.

The federal government through the Department of Agriculture requires germination tests for all seeds that are shipped from one state to another. Germination standards are established for each type of seed. For example, 75 per cent of corn seeds must germinate in order to meet standards, but only 55 per cent of carrot seeds. Containers of any seed which do not meet standards are stamped "Below Standard."

Treatment of seeds. Since water is essential for germination, soaking the seeds in it before they are planted sometimes hastens germination. Some seeds have such tough coats that it is very difficult for water to get into them. Before they are planted, they may be dipped in very hot water or scraped with sharp objects to crack the seed coat. *Legumes,* or plants such as peas and alfalfa, are aided in their growth by certain bacteria that live on their roots. These legumes also add nitrogen to the soil. Some legume seeds, like those of the sweet pea, may be treated with materials containing these helpful bacteria before they are planted. Treating seeds with commercial fertilizer before they are planted may help their growth. Seeds may also be treated to protect the young plants from diseases.

Drawing of a lima bean seed which has been opened to show the embryo from which a complete new bean plant will develop after the seed is planted.



Preparation of the soil. If you have ever had to spade and rake a garden, you probably wondered why in the world it was necessary. There are several reasons why it is desirable to loosen the soil before planting seeds. Germinating seeds and plant roots need oxygen from the air. Air can enter the soil more easily when the particles are not packed together tightly. Young plant roots can grow out into the soil more easily when it is loosened, and rain water can soak into it more readily than when it is tightly packed.

Planting the seeds. The depth to which some common types of seeds should be planted is shown on page 365. Note the relationship of the size of seed to the depth of planting.

Before the young plant in the seed can grow, it must obtain energy and materials to build more protoplasm from the food that is stored in the seed. The stored food, therefore, has to be digested into a simple form that can be used for these purposes. The chemical processes that digest the food require both moisture and heat.

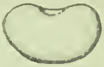
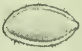
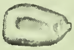
If in the spring it is desirable to get seeds to germinate and grow before it is warm enough outside, *greenhouses, hotbeds,* and *cold frames* are used. Radiant energy from the sun is a principal source of heat in all of these structures, as you can see on page 366. Manure, steam pipes, or electric heating elements may be buried in the soil of hotbeds to provide other sources of heat. Manure warms the soil because it becomes heated as bacteria cause it to decompose. Cold frames have no source of heat other than the radiant energy from the sun.

The young plants grown in greenhouses, hotbeds, and cold frames are called *seedlings.* When the outdoor temperatures become warm enough, the seedlings are transplanted outdoors.

VEGETATIVE PROPAGATION

Some plants can be made to produce additional ones if parts of their roots, stems, or leaves are planted (see page 367). Reproducing plants in this manner is called *vegetative propagation.* Some plants commonly produced by vegetative propagation are listed in the table at right.

Grafting. Plants such as fruit trees are propagated vegetatively by a method called *grafting.* In this process a stem or a bud of one plant is attached to the root or stem of another plant in such a manner that the two parts grow together. Different methods may be used in grafting a stem or bud to another stem or root. Four common methods are illustrated on page 368, and the names of some plants commonly propagated by grafting are listed in the table on page 366.

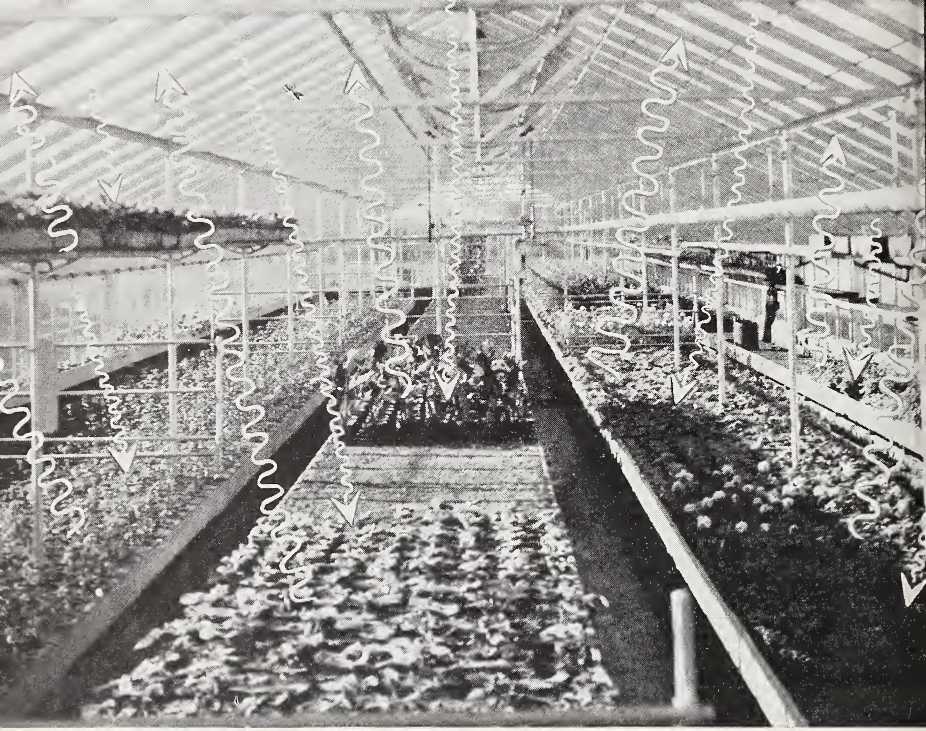
Seed	Comparative Sizes	Depth of Planting in Inches
Bush Lima Bean		2
Squash		1
Corn		1
Radish		$\frac{1}{2}$
Tomato		$\frac{1}{2}$

The depths at which seeds should be planted in the soil usually depend upon the size of the seed. If seeds are planted too deeply, the plants may never come up. In planting seeds one should follow carefully the instructions on the seed package.

SOME PLANTS PRODUCED BY VEGETATIVE PROPAGATION

PLANT	PART USED
Asparagus	root cuttings
Sweet Potato	root cuttings
Strawberry	stem (runner)
Geranium	stem cuttings
Ferns	stem (runner)
Trees	stem cuttings
Begonia	stem or leaf cuttings
Tulip	stem (bulb)
Crocus	stem (bulb)
Dahlia	stem (tuber)

Advantage of vegetative propagation. There are several advantages in propagating plants by a vegetative method. It makes it possible to grow some plants much faster than by using seeds. You can always be sure that the plant produced will be like the parent plant. It is the only way in which seedless varieties of plants like oranges and grapes can be propagated. Some varieties of fruit trees have good quality fruit but possess poor roots and, there-



Lord and Burnham

The shorter waves of radiant energy from the sun pass through the glass of the greenhouse and increase the heat of soil and other materials inside. The longer waves of radiant energy from these heated materials cannot pass through the glass so easily, so that much of the heat is trapped inside.

fore, produce very little fruit. By grafting a stem or bud from such a tree onto the stem or roots of a tree with a good root system, you can obtain a tree that will produce an abundance of high-quality fruit. Grafting has also made it possible to grow several different varieties of fruit on the same tree.

SOME PLANTS PROPAGATED BY GRAFTING

PLANT	PLANT ONTO WHICH GRAFTED	TIME OF YEAR
Almond	Root of almond or peach	Spring
Apple	Root of apple seedling	Spring
Apricot	Stem of apricot or peach	Winter
Cherry	Stem or root of cherry	Winter
Lemon	Stem of lemon seedling	Winter
Orange	Stem of orange seedling	Winter
Peach	Root of peach	Early Fall
Pear	Stem of pear seedling	Winter
Pecan	Root of hickory	Fall
Rose	Root of rose	Winter

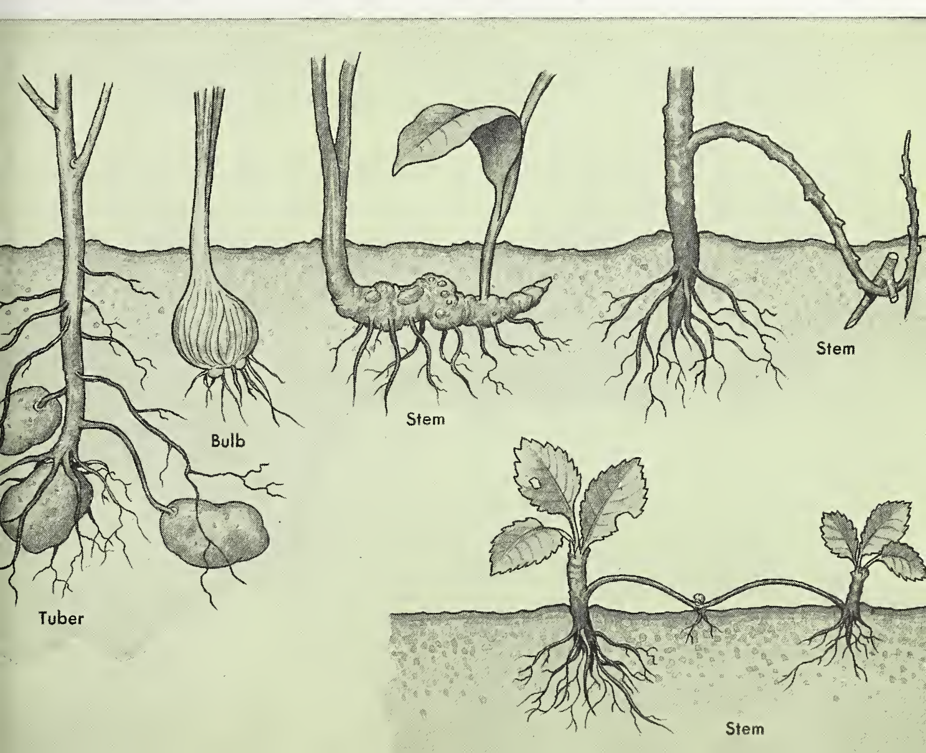
PROPAGATION OF FUNGI

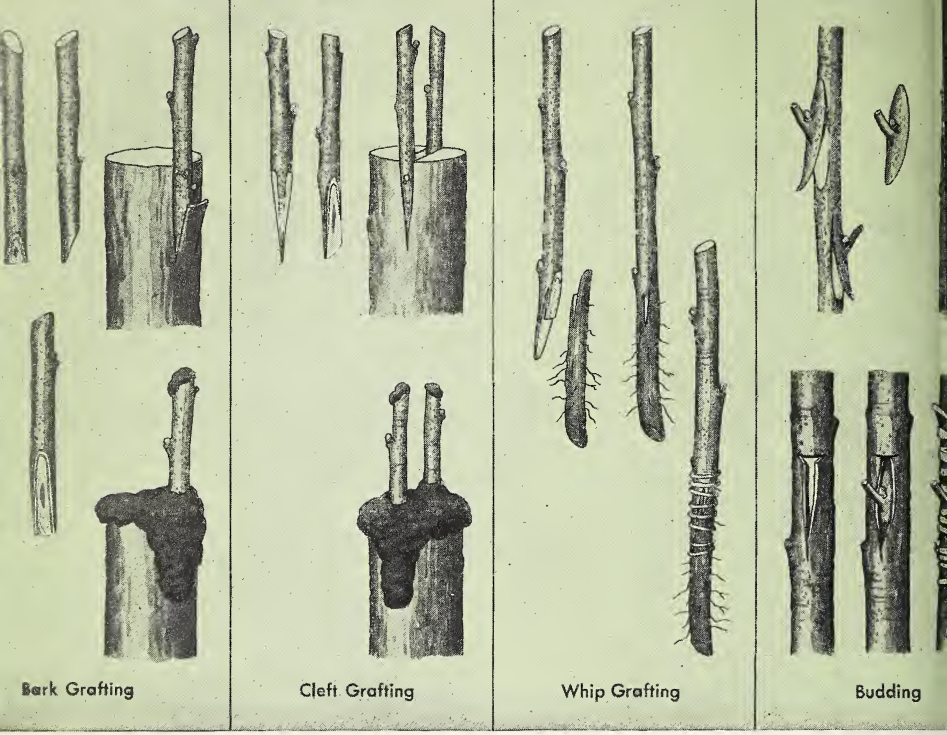
Most of the plants we have considered so far are seed plants. There are other large groups of plants, one of which has no green coloring and is called *fungi*. Bacteria, *yeasts, molds,* and mushrooms are fungi commonly propagated. Whereas green plants can manufacture their own food, fungi cannot. Whenever fungi are propagated, it is therefore necessary to supply a suitable food.

Bacteria. Bacteria are a type of fungi made up of single cells, as shown on page 336. As you will recall, they are so small that it is necessary to use a microscope to see them. Although some kinds of bacteria cause diseases, most bacteria are useful. Bacteria are useful in the production of butter, buttermilk, and vinegar, and in preserving foods such as sauerkraut and dill pickles. They aid in sewage disposal. Certain disease-producing bacteria are used to make the vaccines and serums that protect us from some diseases.

Bacteria cells reproduce by dividing, or splitting, into two cells. When there is sufficient food and moisture available, and when the temperature surrounding them is about the same as the temperature of our bodies, bacteria reproduce very rapidly. To propagate bacteria, food, moisture, and the proper temperature must be supplied.

Examples of ways in which the stems of certain plants can be used in vegetative propagation. The potato tuber is an enlarged underground stem which can be cut into smaller pieces and used to propagate potatoes. The stem of the strawberry plant, lower right, which may produce new strawberry plants, is called a runner.





Four common methods of grafting. The growing layer of cells immediately under the bark must be attached when grafted in order for the grafted stem or bud to grow. As shown in the two examples on the left, the graft is usually covered with wax to protect it.

Certain bacteria use alcohol for food and in so doing form *acetic acid* which causes vinegar to be sour, thus making it useful in flavoring and preserving foods. To produce vinegar, acetic-acid bacteria are put into fermented fruit juices, and the fruit juices are kept at a temperature of about 76°F until the process is complete. During this time the bacteria reproduce very rapidly. It is not always necessary to put acetic-acid bacteria into fermented fruit juice in order to produce vinegar. Some acetic-acid bacteria may already be present, and the production of vinegar will take place if the juice is kept at a suitable temperature. Under such conditions, however, other kinds of bacteria are also present in the juice and will produce substances that result in a poor quality of vinegar.

Bacteria are propagated in laboratories where they may be used for study or to produce serums and vaccines. Various kinds of food are used to grow bacteria in the laboratory. Some bacteria will grow well on boiled potatoes and carrots; others must have special food substances made out of meat or sugar. Still others will not grow in anything but food substances made out of blood. Foods used in growing bacteria are called *media;* as shown on page 339, they are generally kept in test tubes or flat dishes called *petri dishes.* The containers of media are heated at high temperatures in large pressure cookers which are called *autoclaves.* The heat kills all bacteria that may have been in the media; the media are then said to be *sterile.*

Whenever laboratory workers want to grow bacteria, they use one of several methods of planting them on the sterile media. If only one kind of bacteria is desired, a tiny mass of them may be taken from an older growth and transplanted to the sterile media. A thin wire loop is generally used in transplanting bacteria. As you will recall for the experiment on pages 339-340, another method of planting bacteria on dishes of sterile media is to allow bacteria-laden material to touch the media.

After bacteria are planted on the media, the media must be kept at a temperature that is most suitable for their growth. To do this the dishes of media may be placed in bacteria incubators where temperatures can be controlled.

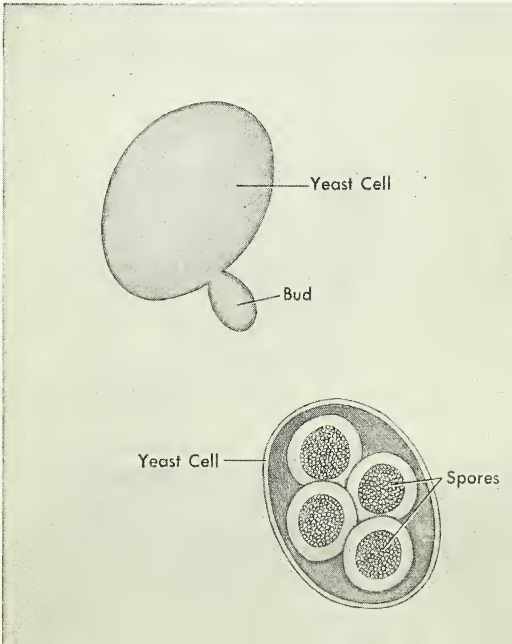
Yeast. Yeast is a single-celled fungus that can use sugar as food. Because yeast cells produce alcohol and carbon dioxide from this food, they are important in making bread and in *fermenting* fruit juices. It is the carbon dioxide produced by yeast that causes bread to "rise." The compressed yeast used in breadmaking is grown in large vats of liquid containing the food material for yeast. After the yeast cells form a thick scum on top of the liquid, they are removed from the vat and pressed into cakes. Whenever the housewife makes bread or hot rolls, she may put a portion of a yeast cake in a warm solution of sugar. Under these conditions the yeast cells reproduce very rapidly.

Mushrooms. The mushroom is another fungus that is commonly propagated for food by the same general methods as those used in propagating bacteria and yeast. Food must be supplied and temperature and light must be controlled. Mushrooms have a rootlike structure of thin strands that penetrate the food material upon which they grow. When pieces of the rootlike strands are planted in suitable food material, new mushroom plants develop.

SUMMARY

The protoplasm in plant cells makes reproduction possible. Seeds that can be used in propagating plants contain

Yeast cells may reproduce by forming buds or producing spores. Spores are usually produced when growing conditions are unfavorable. When conditions again become favorable each spore may develop into a new yeast cell.

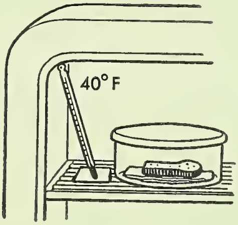


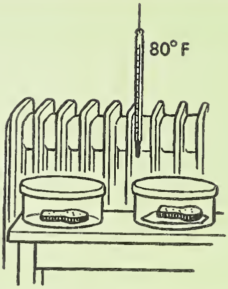
an embryo which developed from an egg cell after it had been fertilized. The embryo depends upon stored food within the seed for its early growth. In order for a seed to germinate, the embryo within it must be alive, and the seed must be put into a moist, warm place. In propagating plants from seeds, we attempt to select those that will germinate and then provide them with the conditions that will encourage growth.

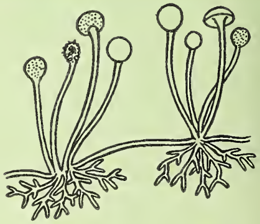
Under certain conditions cells in roots, stems, or leaves of plants may begin to divide and produce another plant. We can propagate plants by separating parts of roots, stems, or leaves from the parent plant and providing them with conditions suitable for growth. Vegetative propagation is used to hasten the propagation of plants and to insure the production of plants like the parent.

Fungi may reproduce by cells dividing, by spores forming, or by parts of the plant breaking off and forming a new plant. Since fungi cannot produce their own food, food from other sources must be made available before they will reproduce in any quantity.

EXPERIMENT






Bread Mold as Seen with Microscope

Question to be answered. Under which of two conditions of heat and moisture does bread mold grow better?

What you need. Three slices of bread from the same loaf; three containers with suitable covers; paper towels; two thermometers.

What to do. Remember that the molds that grow on bread are fungi, and they depend upon the bread for food. Leave the bread exposed to the air in the classroom for several hours, and arrange in containers as shown. Soak paper towels with water in two of the containers, and cover the containers. Place one of these containers in a refrigerator or some other cold place, and keep a record of the temperature. After covering the third container, place the remaining two in a warm place, such as near a heated radiator, and keep a record of the temperature. Observe the bread in each container over a period of two or three days.

Your answer. Why was the bread exposed to air before you began the experiment? What was the difference in temperature between the two situations? In which container did mold appear on the bread first? Was heat and moisture entirely lacking from any of the containers? From where did the bread mold come? Write a sentence that will answer the experimental question.

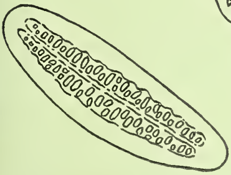
Assumptions in this experiment. What assumptions must you make before accepting your answer?

OBSERVATION

Tomato

Apple

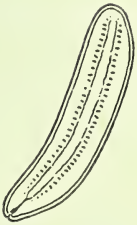
Strawberry



Cucumber

Orange

Plum



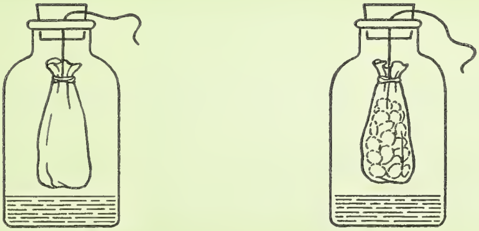
Banana

What to observe. Seeds in different fruits.

How to observe them. Obtain as many of the following fruits as you can, and observe the manner in which the seeds are arranged in or on them: cucumber, tomato, orange, apple, banana, pumpkin, plum, strawberry.

Interpretation of your observation. How were the seeds arranged in each one? How many seeds did you find in or on each fruit? In what way might the fruit aid in distributing the seed? What must be done to obtain large quantities of seed from fruits like these?

EXPERIMENT



Question to be answered. Do germinating seeds give off carbon dioxide as food is used by the growing plants within them?

What you need. Two bottles and stoppers to fit; two pieces of cheese cloth about 6 inches square; 25 germinating bean seeds; lime water.

What to do. Pour about 1 inch of lime water into each of the bottles. Tie 25 germinating seeds into a cheesecloth bag with string and suspend in the bottle as shown ½ inch above the lime water. Tie another bag with nothing in it, and suspend in the same manner. Observe the lime water. As you will recall, when lime water takes up carbon dioxide, it becomes cloudy.

Your answer. Which bottle is your control? How long was it before you noted any change in the lime water? Answer the experimental question.

Assumptions in this experiment. 1. All seeds act like these seeds. 2. Carbon dioxide is the only thing that will cause lime water to become cloudy.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The part of the flower in which the seed is formed is the (a) anther; (b) pollen tube; (c) ovary; (d) petal.
2. When the sperm nucleus combines with the egg nucleus, the process is known as (a) pollination; (b) germination; (c) fertilization; (d) congregation.
3. Bacteria are single-celled plants that (a) are always harmful; (b) can manufacture their own food; (c) reproduce by dividing into two cells; (d) should all be destroyed.
4. In propagating fungi it is necessary to (a) keep them cool; (b) provide them with food; (c) give them plenty of sunlight; (d) soak their seeds with plenty of water.
5. New plants produced by vegetative propagation (a) never produce seeds; (b) are always free from disease; (c) are like the parent plant; (d) are never as strong as the parent plant.

PROBLEM 2. How are animals propagated?

ANIMALS WE PROPAGATE

A number of different kinds of animals are raised for our use. Cattle, hogs, sheep, and chickens, as well as fish, turtles, oysters, snails, clams, lobsters, and frogs, are propagated for food. Many people raise birds, cats, and dogs as pets. Game birds, such as wild duck and quail, are propagated so that there will be larger numbers of them for sportsmen to hunt. Bees are kept for the honey and wax which they produce. Another insect, the ladybird beetle, is propagated for use in destroying undesirable insects.

Main groups of animals. The animals that we propagate are only a small part of the more than 800,000 different kinds of animals which have been discovered on the earth. So that scientists might better understand how animals are related to each other, they have classified all animal life into a number of different groups. Animals are first divided into two main groups, *vertebrates* and *invertebrates.* All animals that have backbones, such as horses and cattle, are called vertebrates, and those without backbones, such as insects and oysters, are called invertebrates. By far the largest number of animals on the earth are invertebrates; many, such as the one-celled protozoa, are too small to be seen without the use of a microscope. Both of these main groups are further divided into a number of smaller groups. Animals in each smaller group have similar structures and reproduce by similar methods.

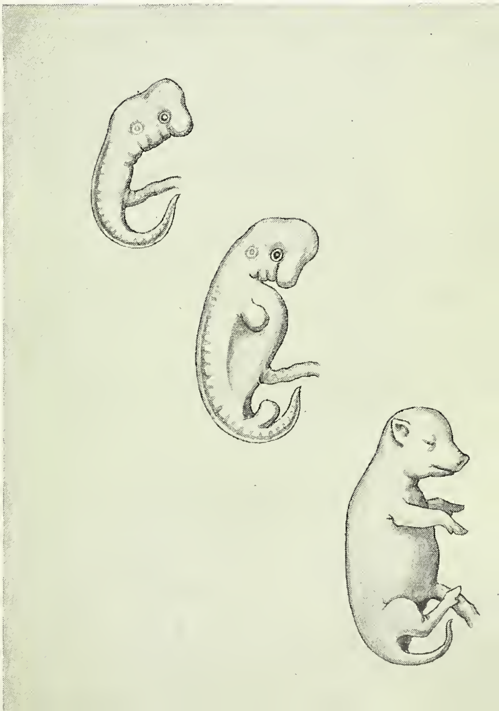
Methods of reproduction. In some animals the process of reproduction is quite simple. Certain of the protozoa reproduce just as bacteria do—by simple cell division. Some groups of animals can reproduce parts of their bodies after those parts have been removed. Flatworms can be cut into a number of pieces, and each new piece will develop into an entire flatworm. If a sponge is cut into small pieces, each piece of the animal may develop into another sponge.

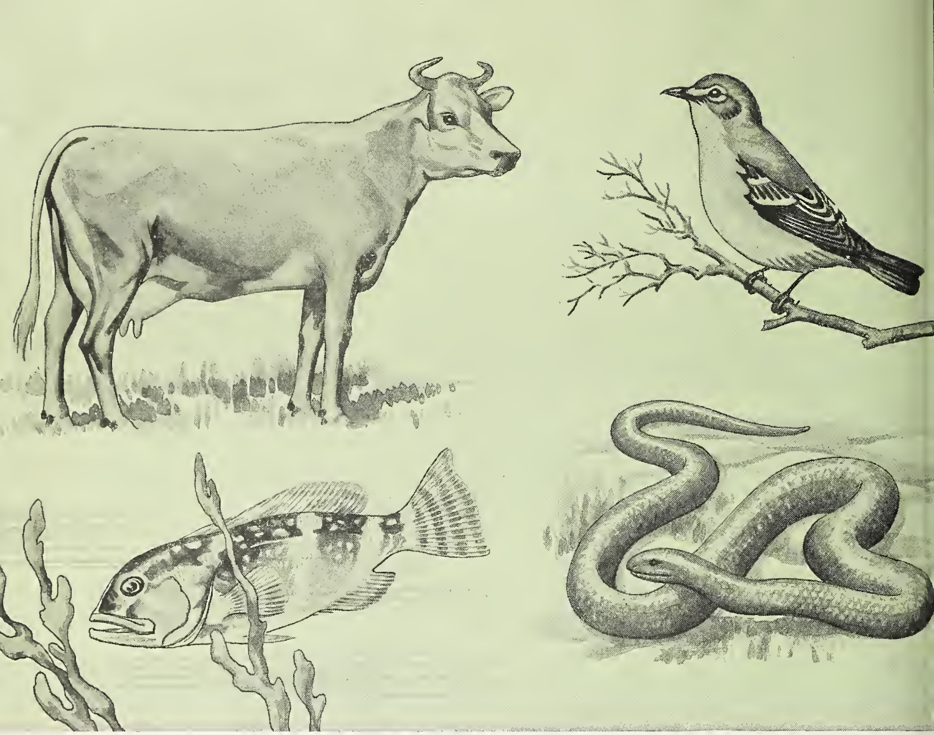
Most of the animals that we propagate, however, reproduce by the union of a male sex cell, called the sperm, and a female sex cell, called the egg. Such a process is known as *sexual reproduction.* As you will recall, flowering plants produce seed by sexual reproduction.

Mammals. *Mammals* are animals, such as the cow, horse, hog, dog, and cat, most of which bear their young alive and feed them with milk from the mother's body. Two sexes, male and female, are necessary for reproduction in mammals. The female produces egg cells, and the male produces sperm cells. The egg is fertilized within the female's body by the sperm. After an egg is fertilized, it begins developing into a young animal, which during its early development is called an embryo.

Although each developing embryo has its own blood system, it obtains food and oxygen from its mother's

Diagram of the development of a pig embryo. It takes four months for the young pig to develop to the stage where it is ready to be born.





Each of these animals has a backbone and therefore belongs to a large group of animals called the vertebrates.

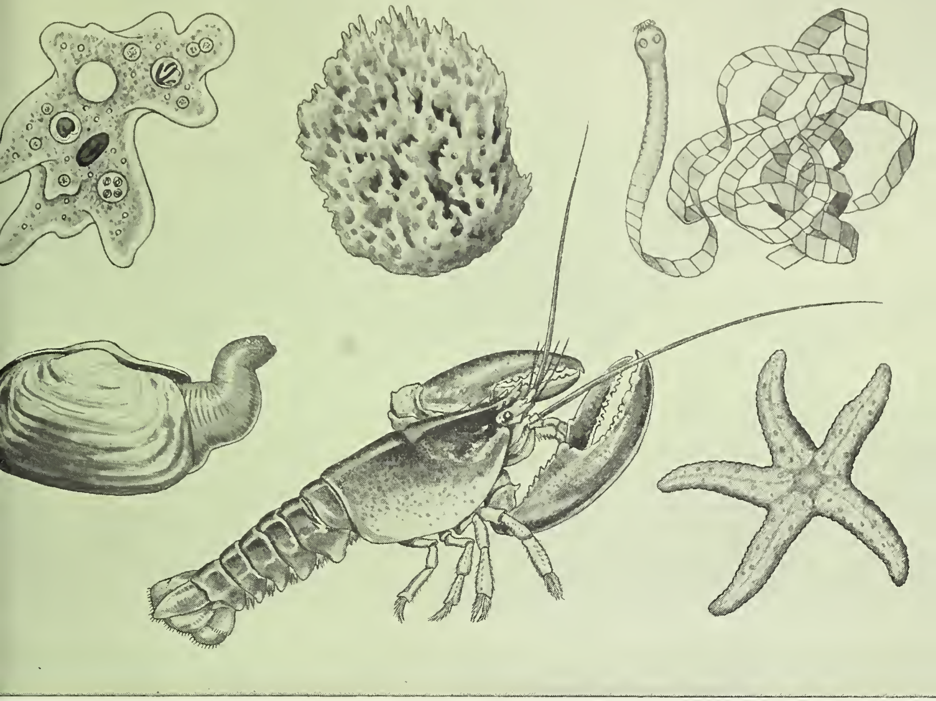
blood. For this reason, it is important that the mother be properly cared for during the period that young are developing in her body. The length of time it takes for a fertilized egg to develop into a young animal that is ready to be born varies among mammals, as shown in table at right.

Mammals which we propagate are not generally allowed to produce young until they have completed their growth. Hogs and sheep complete their growth when they are about one year old; cows and horses in about two years.

Birds. Birds reproduce by laying eggs in which the embryo develops. The egg cell, produced by the female bird, is fertilized in her body. The yolk and white of the bird's egg along with the fertilized egg cell are covered by a shell within the female's body before the egg is laid. After the egg is laid, it

PERIOD BETWEEN FERTILIZATION OF THE EGG AND BIRTH OF THE YOUNG IN CERTAIN MAMMALS

MAMMAL	NUMBER OF MONTHS
Horse	11 Months
Donkey	12 Months
Cow	9½ Months
Sheep	5 Months
Hog	4 Months
Dog	2 Months
Cat	2 Months
Rabbit	1 Month



Some animals without backbones (invertebrates) including a one-celled animal, the ameba, which can be seen only with a microscope; a sponge; a tapeworm; a clam; a lobster; and a starfish.

must be kept warm or *incubated* until the fertilized egg cell develops into a young bird ready to be hatched. By the time the egg is hatched, all of the yolk and white of the egg have been used by the young bird as food.

By collecting the fertile eggs of chickens, turkeys, ducks, and game birds and incubating them, we can propagate these birds. Sometimes hens incubate the eggs, but generally large electrically-operated incubators are used. In hatcheries incubators holding as many as 4,000 eggs are used to hatch chickens, turkeys, or ducks.

After the young birds are hatched, it is necessary to provide suitable shelter for them. Sometimes older birds look after them, but generally the young birds are kept in *brooders*. These sheds or buildings contain heating units around which the young birds can gather to keep warm. Suitable food and water are also supplied in a brooder.

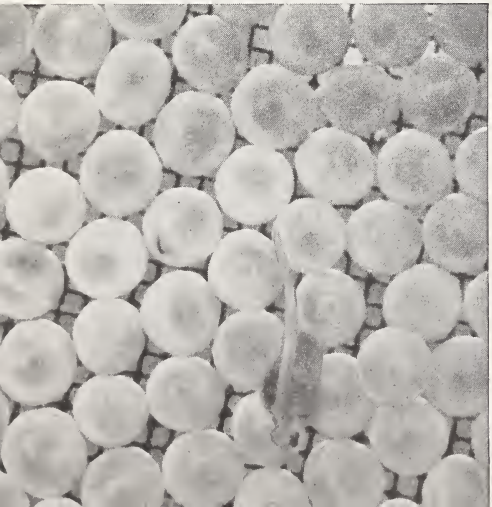
Oysters. Oysters are a valuable source of protein food obtained from the coastal waters of the United States. In 1883 Maryland's half of Chesapeake Bay produced 15 million bushels of oysters; however, in 1945 it was yielding only 3 million. This loss in food production is estimated to be equal to the meat that could be obtained from 200,000 fat beef cattle. Since 1883 much has been learned about the

N.Y. State Conservation Department

In order to increase our supply of fish, such as the lake trout shown above, eggs are taken from the female during the spawning season. The eggs are fertilized with milt taken from the male in a similar manner.

Hatching trays for fertilized fish eggs are placed in long shallow tanks through which cool fresh water flows. Note the newly-hatched lake trout.

N.Y. State Conservation Department



propagation of oysters. The application of this knowledge is doing a great deal to increase production.

Both the eggs of the female oyster and sperm of the male are ejected into the open water where under proper conditions fertilization will take place. Within 24 hours after fertilization, a microscopic free-swimming, feeding larva begins its development. In 15 days the larva has grown to about the size of a fly speck, and seeks a clean, hard surface on the bottom on which to attach itself. From here on, it remains in one place and depends upon tidal currents of water to bring it the microscopic organisms upon which it feeds. If the larva does not find a suitable place to attach itself, it dies.

By experimentation it has been found that oyster production can be increased by dumping old oyster shells into the water. These shells sink to the bottom and form beds upon which the oyster larvae can attach themselves.

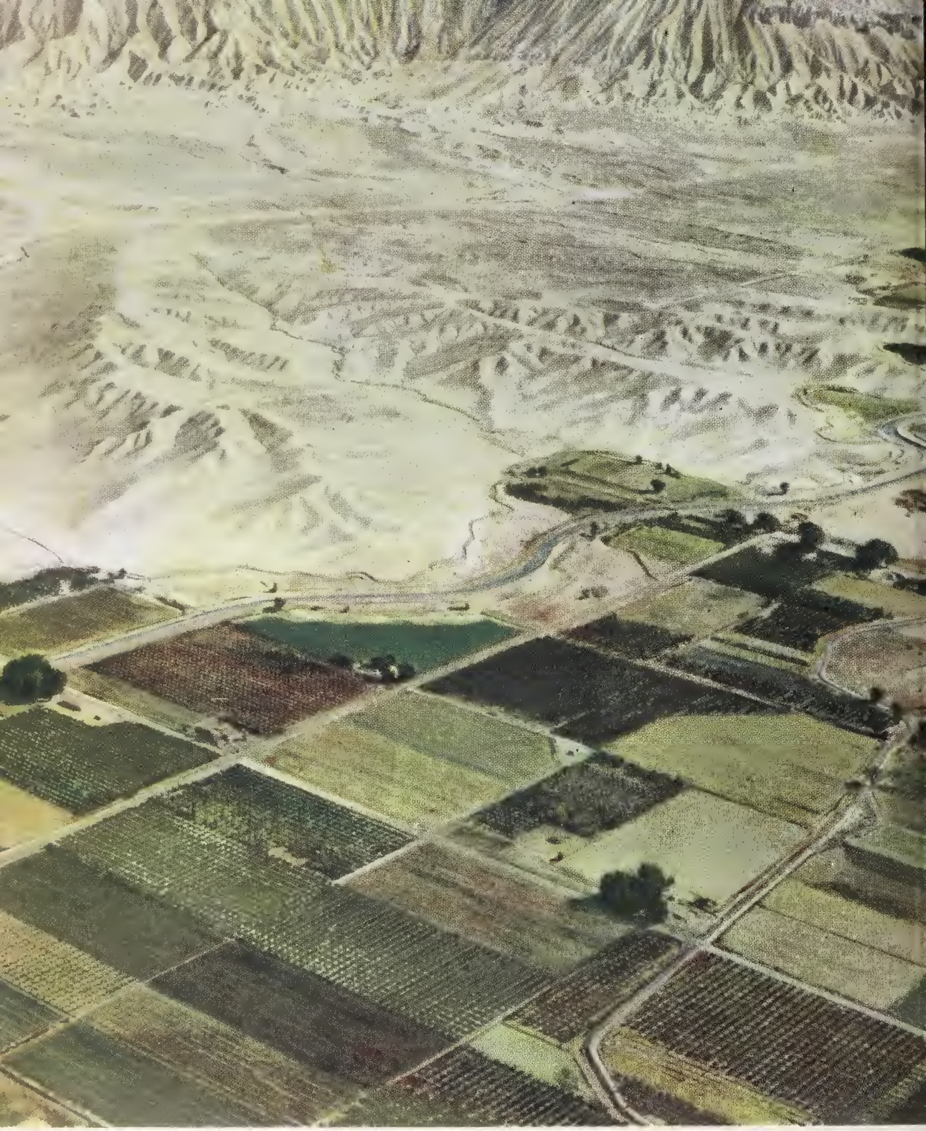
Fish. Many fish hatcheries are operated in the United States. Fish reproduce sexually in much the same manner as oysters. The female fish lays her eggs or *spawns* in the water. The male fish releases sperm, called *milt,* into the water nearby. Under these conditions as is true with the oyster, only a few of the many thousands of eggs laid by the female may be fertilized. Many of those which are fertilized may later be eaten by fish and other animals. The number of fish, therefore, produced under natural conditions is small compared to the large number of eggs laid by the female. See picture at left for what we do about it.

SUMMARY

We have not been able to obtain

U. S. Forest Service

Snow like this on high mountains melts slowly during spring and early summer, providing a constant source of water for irrigating crops in the valleys below.

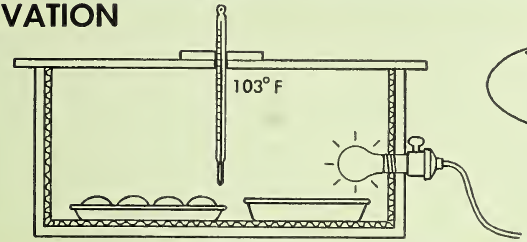


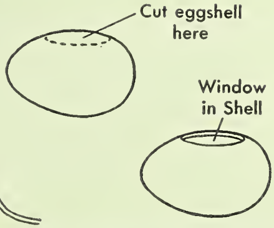
Laurence Lowry

Large-scale irrigation can change a barren desert to rich farm land. This is a portion of the Grand River Valley project in the Upper Colorado Basin, showing farms reclaimed from the hot dry sand in the background.

sufficient animals to meet our needs by depending upon them to reproduce under natural condition. It has, therefore, been necessary to control conditions so that desirable animals will reproduce in larger numbers. Most of the animals that we propagate reproduce sexually. We attempt, therefore, to control conditions so more fertilized eggs will develop.

OBSERVATION





What to observe. Development of chick embryo.

How to observe it. Build an incubator from a wooden box about 1 foot square on the end and about 24 inches long. You will need two boards or panes of glass to cover the box, an electric lamp, a thermometer, a pan of water, a tray, and a dozen fertile eggs. Line the box with corrugated paper to insulate it. Install the lamp, which is to serve as the heating unit, in one end of the box as shown. The pan with the water in it should be placed under the lamp. This is the humidifier. Place the tray in position as shown. Suspend the thermometer between the two boards or panes of glass. Turn on the lamp and keep a record of temperature for two days. Regulate the temperature by opening the crack in the cover or by changing the size of the lamp until the temperature remains constant at 103°F.

After the incubator is properly regulated, place the eggs in the tray. Mark each egg with an X on the side that is up. Each day the eggs should be turned so that one day the X's are up and the next day all are down. Keep the pan filled with water.

After four days, remove an egg and place it on a warm cloth pad. With fine-pointed scissors puncture the shell and cut a hole in the top. Remove the shell and observe the embryo. It may be that you will have to pour the contents of the egg into a small dish to observe the embryo. Open one egg each day to observe the way the embryo grows and develops.

Interpretation of your observation. What is necessary before a little chick will develop in the egg? What are some of the first parts of the embryo that you can see? How could you tell that all of the eggs you used were fertile?

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Animals with backbones are called (a) mammals; (b) invertebrates; (c) vertebrates; (d) fungi.
2. The developing embryo of a chicken differs from that of a pig since (a) it does not develop from a fertilized egg; (b) it obtains its food in the same manner; (c) it grows more slowly; (d) it develops outside the female's body.
3. The eggs of oysters are fertilized (a) in the mother's body; (b) by sea water; (c) by sperms; (d) by spores.
4. Most of the animals we propagate reproduce by (a) sexual reproduction; (b) vegetative propagation; (c) forming spores; (d) spawning.

CHAPTER ACTIVITIES

REVIEW YOUR UNDERSTANDING

Several ways of propagating plants and animals are listed below, followed by the names of a number of different kinds of plants and animals. Beside the number of the method of propagation, write in the proper place on your answer sheet the letter of the plant or animal so propagated.

METHODS OF PROPAGATION

1. Collecting and planting seeds
2. Using parts of a plant such as the stem, leaf, or root
3. Collecting eggs and keeping them where they will hatch
4. Grafting

PLANTS AND ANIMALS

a. Strawberry
b. Bean
c. Fish
d. Orange
f. Corn
g. Oyster
h. Potato
i. Quail

ANALYZE AN EXPERIMENT

John, a member of a high-school science class, filled a quart jar about a quarter full of germinating bean seeds. He then sealed it airtight and allowed it to stand overnight. At the same time, he filled a similar jar about a quarter full of dry bean seeds and sealed it. The next day he thrust a lighted match into the jar containing the germinating seeds, and found that it immediately went out. He then thrust a lighted match into the jar containing the dry seeds, and found that the match burned for a short time before it went out.

Following are a number of statements regarding John's experiment. Write the numbers of the statements about the experiment that you accept in the proper place on your answer sheet.

1. The experiment could be used to answer the question, "How many bean seeds would germinate?"
2. The experiment could be used to answer the question, "Do germinating seeds use oxygen?"
3. The experiment proved that germinating seeds die when sealed in a jar overnight.
4. The jar containing dry bean seeds was used as a control.
5. The burning match went out immediately in one jar because it was cooled below the kindling point.

Bureau of Plant Industry, Soils, and Agricultural Engineering

By special care, vegetables such as these cucumbers can be grown without soil, in vats of chemical solutions. In this project, the wire netting over the vats containing the chemical solutions is covered with straw.

chapter 20 CARING FOR PLANTS

ONE of the big problems facing many people of the world today is that of obtaining sufficient food. It has been reported that world food production will have to be increased several times if all people of the world are to be properly fed. Since nearly all our food comes either directly or indirectly from green plants, we must look to them as the means of increasing food production. An understanding of how plants manufacture food will help us to see what man can do to increase food production.

PROBLEM 1. How do plants manufacture food?

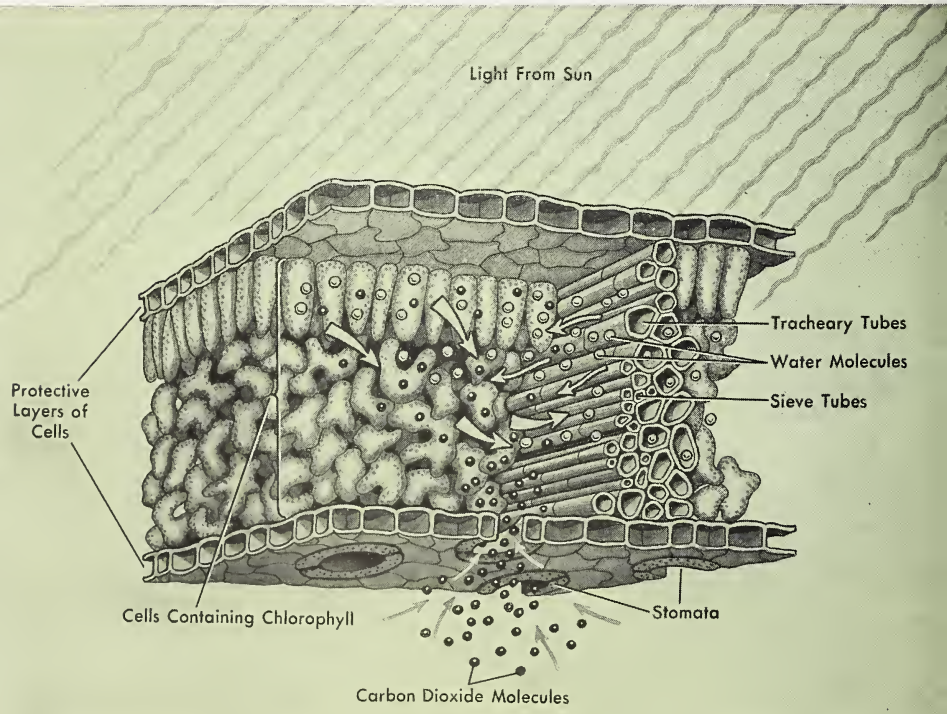
HOW GREEN PLANTS MAKE FOOD

Early ideas regarding plant food. It was believed at one time that plants obtained their food from the soil. It had been observed that plants had to receive water from the soil in order to grow. But the trunk, branches, and leaves of trees were something more than water. The food stored in roots, stems, and seeds of plants was quite different from water. It was therefore believed that plants took some kind of food out of the soil in addition to water.

About three hundred years ago a Belgian chemist, van Helmont, became interested in this problem. Being a scientist, he devised an experiment to answer the question: Do plants take anything other than water from the soil? He carefully weighed a barrel of soil from which all water had been removed and then planted a tree seedling in it. Only distilled water was added to the soil. After five years a tree weighing 169 pounds had grown in the barrel. When the tree was removed and the soil weighed, van Helmont found that it had lost only two ounces. He therefore concluded that the water alone had produced the tree.

It was later discovered that when

Drawing of a cross section of a green leaf to show the movement of water, carbon dioxide, and food during photosynthesis. The smaller arrows indicate the movement of water from the tracheary tubes and larger arrows indicate the movement of food-bearing sap into the sieve tubes.



green plants were illuminated, they took in carbon dioxide. So it was concluded that plants used carbon dioxide as food. Today, however, we know that carbon dioxide and water are not true foods for plants.

Manufacture of sugar with light. From carbon dioxide and water a green plant manufactures sugar which it later uses to produce starch and other types of food. All foods produced by plants contain the chemical elements carbon (C), hydrogen (H), and oxygen (O), obtained by the plant from carbon dioxide (CO_2) and water (H_2O).

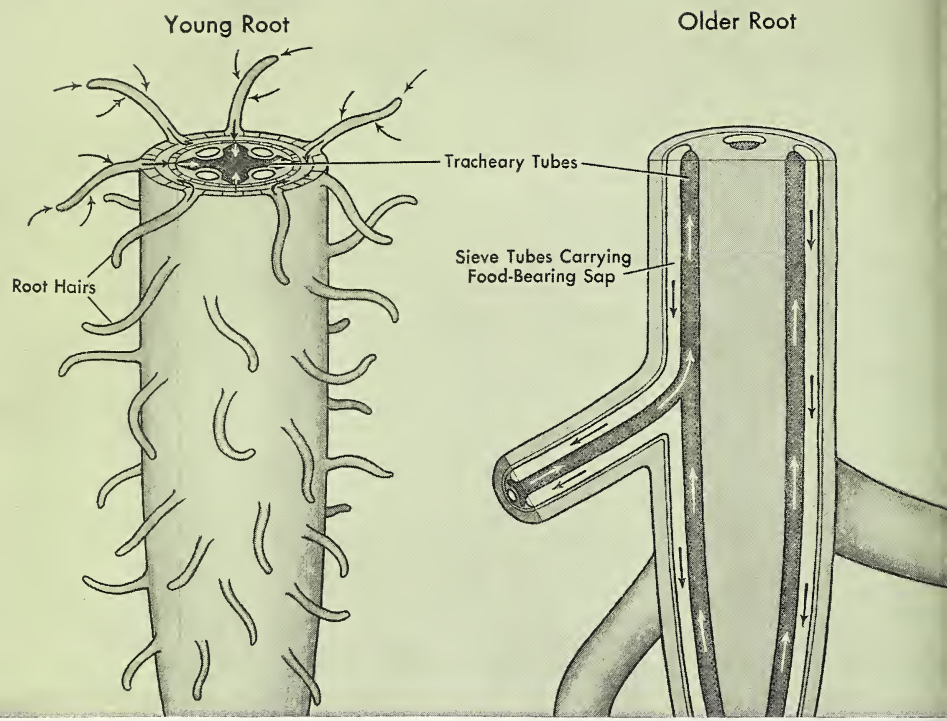
Energy is needed to break down carbon dioxide and water and recombine their atoms of carbon, hydrogen, and oxygen into sugar. The essential energy is obtained from sunlight by green coloring matter in plant cells called *chlorophyll*. The process of using light as energy in making food is called *photosynthesis*. The demonstration on page 384 will help you see that light is necessary for photosynthesis. Although any plant cell containing chlorophyll may carry on photosynthesis in the presence of light most of the cells containing chlorophyll are located in the leaves. If you were to cut a very thin slice through the edge of a leaf and examine it under a microscope, you would see plant cells somewhat like those shown on page 380.

Production and storage of other foods. Plants make starches, proteins, and fats out of the sugar produced by photosynthesis. As you will recall, both sugar and starch are called carbohydrates. Starch is a form of carbohydrate that can be stored in various parts of the plant: in roots, stems, leaves, fruits, and seeds. Protein is a special kind of food containing carbon, hydrogen, and oxygen, all obtained from the sugar, and nitrogen and sometimes sulfur and phosphorus, which come from other sources. Proteins are used in producing more protoplasm in the plant, and are usually found in large quantities in seeds. Fats contain the same elements that carbohydrates do, although they contain less oxygen. Fats are stored in considerable quantities in the seeds of some plants. Starches, proteins, and fats are believed to be built up from sugars. These foods are formed in the parts of the plant where they are found. Neither chlorophyll nor light is necessary for making these foods from sugar.

HOW PLANTS USE MATERIALS

Obtaining water. One of the raw materials for manufacturing food is water. It also carries other raw materials, manufactured food, and wastes throughout the plant. Plants use more water than any other one substance. It has been estimated that it takes 368 pounds of water to produce one pound of water-free corn plant material. Although one corn plant will use over a gallon of water a day, only about 1 per cent of it goes to make food; the remainder is lost from the leaves by evaporation. The parts of the plant which supply it with water are shown on page 382.

As you will recall, molecules of water are in constant motion. As these molecules in films of water surrounding soil particles move about, some of them strike the thin cell wall of the *root hair* (see page 382). As is true of the cell membrane in our bodies (see page 315), water molecules can pass



Young roots are covered with root hairs through which water and dissolved minerals in the soil enter the water-conducting tubes of the plant (see arrows). Older roots provide support to the plant and a conducting system of tubes through which water and food-bearing sap are transported.

through tiny openings in the cell wall of the root hair. The water molecules in the soil outside the root hair are generally closer together (more concentrated) than those inside the root hair. Many more molecules are therefore hitting the outside of the cell wall than are hitting the inside. For this reason more molecules pass into the root hair than out of it. This passage of water molecules through a cell wall is called *osmosis.*

Conducting water. As the root hair takes on more water from the soil, the water passes toward the center of the root by osmosis. It soon enters tube-like cells, called *tracheary tubes,* that extend from the roots through the stem into the leaves. The veins of leaves are very fine projections of tracheary tubes which conduct water into the leaf.

Obtaining carbon dioxide. Carbon dioxide given off by living things, and from other chemical processes where burning takes place, is released as a gas into the air. It makes up, however, much less than 1 per cent (0.04 per cent) of the air. Small though this is when compared with the percentages of oxygen and nitrogen in the air, it is sufficient to supply all plants.

Leaves are constructed so that they can obtain carbon dioxide and other gases directly from the air through very fine openings called *stomata* or *stomates*. As can be seen on page 380, the stomata open into air spaces within the leaf. Because there are more molecules of carbon dioxide in the air outside the food-making cells than inside, carbon dioxide passes into the cells. Stomata not only allow carbon dioxide to pass into the leaves; they also allow water vapor to escape from the interior of the leaves, a process called *transpiration*. Between 90 and 99 per cent of the water which a plant absorbs from the soil is lost by transpiration.

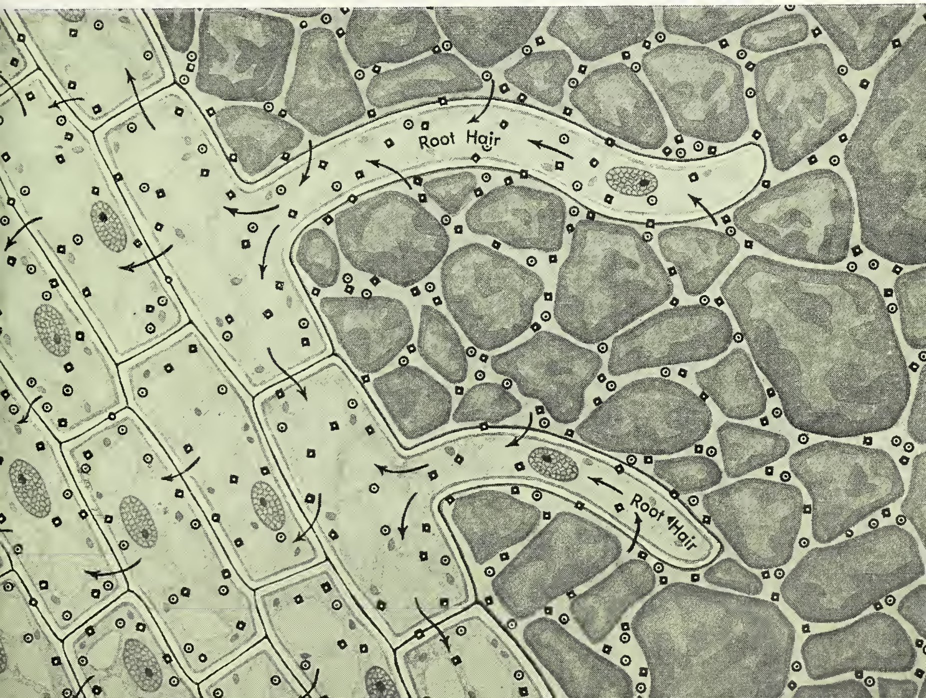
When the elements from carbon dioxide and water are combined to produce carbohydrates, not all the oxygen is used. The extra oxygen is released into the atmosphere where it can again be used by living things.

Transporting food. The carbohydrates produced in leaf cells may be used as food by the plant or may be stored for future use. In either case, the food must be moved from the cells where it is manufactured to the cells where it is used or stored. Most of it is transported to various parts of the plant by tubelike structures called *sieve tubes* in the roots, stems, and the veins of leaves. As in our own bodies, foods have to be in simple forms (small molecules) before they can pass from one cell to another, however.

OTHER ESSENTIALS FOR GROWTH

Mineral elements needed by plants. It has already been pointed out that plants need nitrogen, sulfur, and phos-

In this drawing the circles represent water molecules and the squares represent dissolved minerals as they enter root hairs from the soil by osmosis. From the root hairs, water and dissolved minerals pass from one cell to another by osmosis in the direction of the arrows.



phorus in order to make protein. Iron, potassium, and manganese are needed in making chlorophyll. Other elements, such as *boron,* calcium, and iodine, are also necessary for healthy plants. All these elements are obtained from minerals in the soil. In order to enter the root hairs and be carried throughout the plant, the minerals have to be dissolved in water.

Essential oxygen. As we do, so do plants need energy to carry on their life processes; green plants obtain energy from the food they manufacture. As you have already seen, oxygen must be combined with the food in order to release energy. Plants can use the oxygen given off as a by-product of photosynthesis, but they also obtain oxygen from the air through stomata in the leaves and small openings in the stems of plants. Oxygen may also enter the plant through the thin walls of root hairs in the soil.

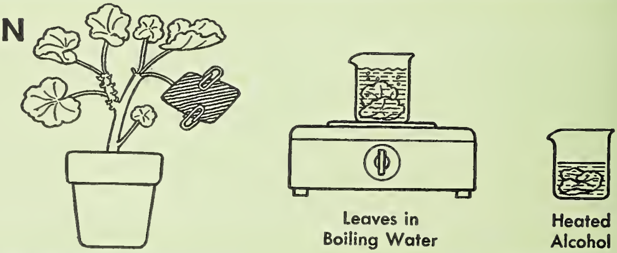
Effects of temperature. Chemical processes resulting in the growth of plants are affected by extremes of temperature. Although some plants can carry on photosynthesis at low temperatures, most crop plants are destroyed or seriously damaged by freezing. If you live in a climate where frosts occur, you have probably seen plants turn black after a frost.

High temperatures like those in dry, hot, desert climates may also cause large water losses from plants by transpiration. Desert plants like the cactus have structures which protect them from such water losses.

SUMMARY

All living things are dependent upon the action of chlorophyll in manufacturing food in plant cells. By using sunlight as a source of energy, green plants change carbon dioxide and water into elements which are recombined to form sugar. Plants convert the sugar manufactured by photosynthesis into starches, proteins, and fats. Chlorophyll-bearing plants are constructed so that they can make and store food. Environmental conditions, including light, temperature, and moisture, affect the food-making processes of various plants.

DEMONSTRATION



Generalization to be demonstrated. Photosynthesis occurs only in the presence of light.

What you need. A potted geranium plant; water; iodine solution;

rubbing alcohol; source of heat, such as an electric hot plate; two beakers; black paper; paper clips.

What to do. Carefully cover one of the leaves of the geranium plant with black paper, making sure that no light can get to the leaf. Hold the paper in place with paper clips. Allow the plant to remain in the light for two days. Remove one of the leaves that has been exposed to the light and place it in water heated to the boiling point. After two minutes transfer the leaf to some alcohol which has been heated. (*Caution:* Care should be taken in heating the alcohol, since fumes from it may be lighted by an open flame. A beaker containing the alcohol should be heated by being placed in boiling water which has been heated over an electric hot plate.) After the leaf has become yellow, remove it from the alcohol and spread it out on a flat surface. Cover the leaf with iodine solution. Note any color change. Now remove the leaf which has been covered with black paper and treat it in the same way.

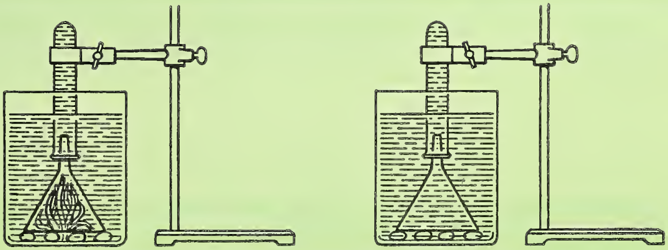
What to observe. What difference in color resulted from placing iodine on the two leaves? (See the experiment on page 332.)

What does it mean? 1. What evidence is found in this demonstration to show that a plant needs light to produce starch?

2. How does this demonstration support the generalization, "Photosynthesis occurs only in the presence of light"?

A basic assumption in this demonstration. The presence of starch in a leaf is evidence that photosynthesis has been taking place. What are some of the other assumptions in this experiment?

XPERIMENT



Statement to be tested. Oxygen is released from plants as photosynthesis takes place.

What you need. Two battery jars or large beakers; two glass funnels; two test tubes; sand; water; several small stones; water plants such as Elodea or eel-grass.

What to do. Wash sand thoroughly, and place about an inch of it in the bottom of each jar. Fill one jar about three-fourths full of water and plant several Elodea or eel-grass plants near the center of the jar. Fill the other jar to the same level with water but do not put any plants in it. Arrange the large end of one funnel over the plants, supporting it by small stones placed in the sand around the plants. The stem of the funnel should be an inch or two beneath the surface of the water. Fill a test tube with water and place it in an inverted position over the stem of the funnel, taking care to see that no air enters the test tube.

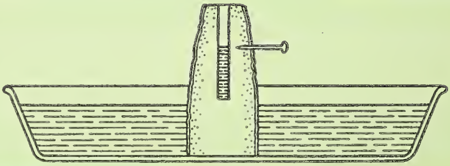
In the same way, invert the other funnel and test tube in the jar which contains no plants. Place both jars in bright sunlight until the test tube in one of the jars is over half full of gas. This may take several days. Remove the test tube containing the gas, closing it immediately with the thumb so that the gas cannot escape. Insert a glowing splinter into the gas. If the splinter burns, oxygen is present.

Does this evidence test the statement?

Some basic assumptions in this experiment. 1. The oxygen collected in the test tube was a result of photosynthesis.

2. Other land and water plants act in the same manner as these plants.

OBSERVATION



What to observe. A result of osmosis in plants.

How to observe it. Cut off the small end of a carrot so that the remaining part is about 3 inches long. Cut squarely across the larger end of the carrot so that the carrot will stand alone when placed on that end. Using a knife or cork borer, make a "cup" about 2 inches deep in the center of the small end of the carrot. Fill the "cup" about half full of a thick syrup and stick in a pin to mark original level. Now stand the carrot on its larger end in a shallow pan containing about 2 inches of water. Observe the level of the syrup after several hours have passed.

Interpretation of your observation. Write one sentence explaining why the amount of liquid in the "cup" of the carrot increased.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each of the following statements.

1. The process by which plants obtain water through their roots is known as (a) photosynthesis; (b) transpiration; (c) osmosis; (d) propagation.
2. The first step in photosynthesis is thought to be the manufacture of (a) sugar; (b) starch; (c) protein; (d) fat.
3. Carbon dioxide from the air enters a plant through (a) root hairs; (b) sieve tubes; (c) stomata in the leaves; (d) tracheary tubes.
4. In order that minerals can be taken up by the roots of plants, the minerals must (a) be combined with oxygen; (b) be dissolved in water; (c) have been put into the soil by man; (d) contain a large amount of nitrogen.
5. The energy needed by plants to carry on their life processes is obtained when the food they manufacture combines with (a) oxygen; (b) water; (c) carbon dioxide; (d) minerals.

PROBLEM 2. How can the physical conditions affecting plants be controlled?

WATER IN THE SOIL

Composition of soil. Soil is a mixture of many things. It contains both living and nonliving material. The tiny particles that make up the main part of soil are nonliving materials formed from rock, called *inorganic matter*. The living material consists of bacteria, plant roots, worms of various kinds, insects, and other small animals, or the remains of these things. These substances are called *organic matter*. Some of the organic matter in the soil is partially decayed; in this condition it is called *humus*. All soils contain water and air.

There are a number of different kinds of soil. Those composed mostly of coarse particles of rock are called *sandy soils*. Others made up mostly of fine particles are called *clay soils*. Some soils contain a large amount of organic matter; other soils contain very little. *Loam* soils contain both sand and clay as well as a good supply of humus.

Soil water. Root hairs of plants obtain most of their moisture from a film of water surrounding soil particles. It has been found that there is a close relationship between the size of soil particles and the soil's capacity to supply plants with water.

Fine-particled soil, such as clay, will hold large quantities of water, but it holds the water so tightly that plants can obtain little from it. It is therefore difficult to raise plants in clay soils. Although the particles of sandy soil are large and do not hold much water, such soil will readily give up what little water it holds. Plants do not grow well in sandy soil unless water is constantly supplied. Loam soil is a mixture of clay, sand, and organic matter or material produced by living things. Loam soils are excellent for plant-growing because they have good

U.S. Department of Agriculture

A field of red clover is being plowed under as green manure in preparation for planting a crop such as corn or wheat.

water-holding and water-giving characteristics. Clay and sandy soils can be improved by adding organic matter to them. There are also certain commercial products which can be used to prevent soil from packing and getting hard.

Irrigation. As you will recall from Chapter 16, irrigation of crops is one of the ways in which man adjusts to climates where the rainfall is limited. In such climates, the atmosphere is so dry that plants lose large amounts of water through transpiration. The farmer, therefore, has to irrigate his crops as many as five or six times during the summer. To irrigate crops such as corn or beans, water is run in small ditches between the rows. The entire field is flooded in irrigating crops such as wheat. The soil is soaked to a depth of about 8 to 10 inches. If it is soaked any deeper than about two feet, much of the water drains away before the plant can use it.

Drainage of soils. Whenever soils do not drain properly, all the air spaces between soil particles may become filled with water. Under such conditions, soils are unsuitable for growing plants. Different methods are used for draining excess water from soils. One method is the open ditch, which drains off water. Since it is inconvenient to farm a field so cut up, crop land is often drained by porous clay pipes, buried end to end, which carry off the excess water.

MINERALS FROM FERTILIZERS

Mineral elements. A number of different kinds of tests have been developed to determine when soils lack sufficient amounts of the chemical elements necessary for proper growth of plants. Many state agricultural experiment stations make chemical tests of soils free of charge for a farmer and a homeowner living in the state. He is given a report of the test along with recommendations as to what to do to improve his soil.

Fertilizers from living things. When it is clear that essential elements are missing from the soil, *fertilizers* containing the elements should be added. Manure from cattle, horses, or sheep is one type of organic matter containing a number of elements plants need. It is therefore commonly used by farmers in fertilizing their soil. Green plants with high nitrogen content are also plowed under as fertilizers; they are called *green manure.*

Other kinds of animal products added to the soil to increase the chemical elements needed for plant growth are bone meal, fish cake, dried blood from slaughterhouses, and *guano* (bird manure).

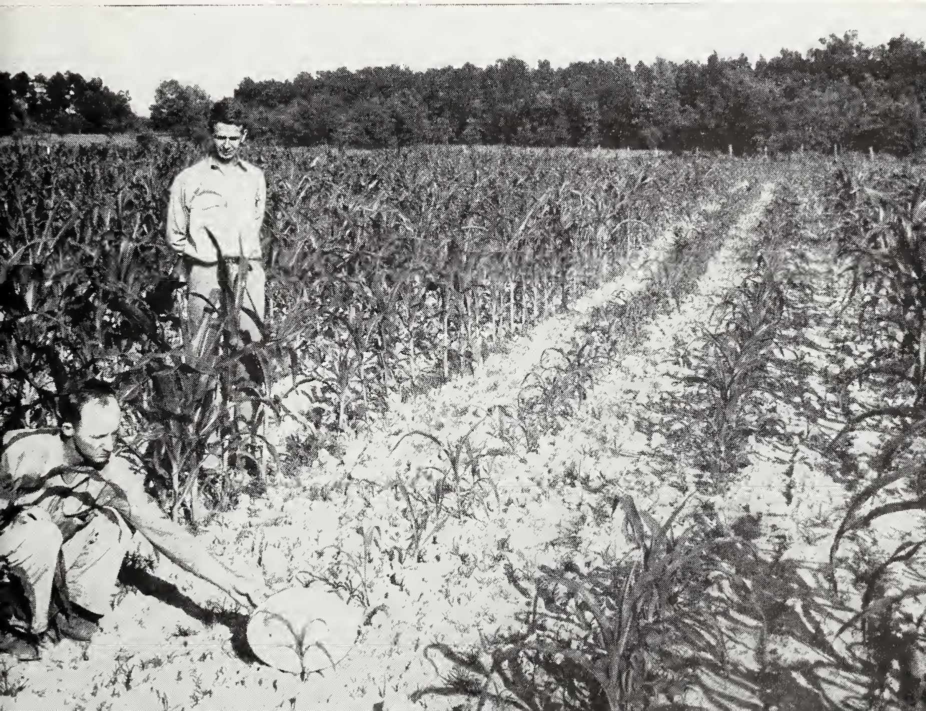
Commercial fertilizers. Today most of the nitrogen, phosphorus, and potassium used in fertilizing the soil comes from what are called *commercial fertilizers.* The materials used in making commercial fertilizers may be obtained from natural sources or they may be manufactured. Natural sources are deposits of nitrate of soda, found in Chile; potassium; and rock phosphate, mined in several different countries. Nitrogen in the air is used in manufacturing nitrogen compounds for fertilizers.

The natural deposits of materials containing elements used for fertilizers are not distributed equally throughout the various countries of the world. Proper distribution and use of soil fertilizers are extremely important in feeding the people in all parts of the world.

Fertilizers in sprays. The practice of supplying nitrogen to plants through the leaves rather than through the roots has been tested with some success. It has been found that spraying apple trees with a fertilizer containing nitrogen increases the amount of fruit and improves the color of it.

When the mineral elements essential for plant growth are lacking in the soil, plants are starved, as shown where the man is holding his hat. Organic fertilizers obtained from plants and animals or commercial fertilizers produced directly from chemical compounds supply the essential mineral elements.

U.S.D.A. Photograph



OTHER FACTORS IN GROWTH

Light. Although sunlight is used by green plants in manufacturing food, too much of it may damage some plants. When cabbage or tomato seedlings are taken from hotbeds and planted in gardens, many of their roots are broken off. Until new roots have developed, each little plant has difficulty in obtaining sufficient water. Sunlight raises the temperature of the leaves and increases the amount of water evaporated from their surfaces. Therefore young seedlings are often protected by some type of covering, until their roots can absorb enough water to keep the plants from wilting and dying.

Plant scientists have discovered that the periods of darkness and light during each 24-hour day regulate flowering time in many plants, such as tobacco, onion, soybean, and chrysanthemum. Some plants will form flowers sooner when the period of daylight is long, whereas other plants will form flowers sooner when it is short. Still other plants do not seem to be influenced in their blooming by the amount of daylight and darkness. Certain varieties of plants will not bloom and produce seed if they are grown in latitudes where the length of day is not suitable for flowering.

It is not practical to regulate light conditions on large fields to control the blooming time of plants. It has therefore been necessary to select those plants that will bloom and produce seed under the light conditions which have proved to be characteristic of each locality.

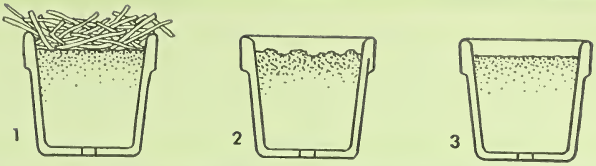
Temperature. We have already seen how hotbeds are used to protect young seedlings from cold temperatures early in the spring. Sometimes it is necessary to protect entire fields of plants from freezing temperatures. Since it takes two years for citrus fruits to develop from blossoms, the fruit has to grow through winter months. Therefore citrus fruits can be grown only where winter temperatures do not generally go below freezing. Even in such places, the temperature may drop below freezing for short periods of time. The methods used by citrus growers, truck farmers, and cranberry growers in meeting such emergencies were described in Chapter 16.

Growing plants without soil. Vegetables and flowering plants can be grown without soil. Sometimes the practice is called *soilless culture,* or *hydroponics.* All soilless methods of growing plants depend upon the use of chemicals, containing necessary mineral elements dissolved in water. The plants may be grown with the roots submerged directly in the solution, or they may be grown in clean sand, cinders, or some other such material kept moistened with the solution.

SUMMARY

Plants develop best when moisture, mineral elements, light, and heat are present in the proper amounts. Whenever there is a deficiency of these materials or conditions, it is possible to aid plants by supplying additional quantities. When too many of the mineral elements or too much moisture, light, or heat are present, steps must be taken to prevent the excess from damaging the plant. It is possible to grow plants without soil by supplying them with the materials they would ordinarily obtain from the soil.

BSERVATION

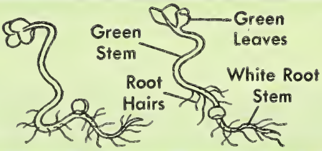


What to observe. The effect of different soil surfaces upon the loss of moisture from the soil.

How to observe it. Fill each of three equal-size flowerpots with garden soil to within a half inch of the top. Add water to the soil in each flowerpot until the soil is completely soaked and will hold no more water. Allow the pots to drain for half an hour, and weigh. Record the weight of each pot. Cover the soil in one pot with a layer of straw; keep the top half inch of soil in the second pot cultivated by pulverizing it with an old fork; and do nothing to the soil in the third pot. Place the three pots of soil in a warm part of the room. Weigh them daily to determine how much water is being lost by evaporation from the soil in each pot.

Interpretation of your observation. What accounts for the loss of weight? Which pot loses weight fastest? Which of these methods would you use to save moisture in the soil of your garden?

OBSERVATION



What to observe. The effect of solutions of fertilizer on plant roots.

How to observe it. Place two or three layers of blotting paper in the bottom of a beaker. Moisten the blotting paper and place a number of radish seeds on it. Cover the beaker and set in a warm place, keeping the paper moist, until the seeds have germinated. Examine the tiny roots and root hairs with a magnifying glass. Now wet some of the roots with a strong solution of a commercial fertilizer like that used on lawns. After a few minutes examine the roots that were treated with the fertilizer.

Interpretation of your observation. In what way did the appearance of the root hairs change? How would you explain what happened? Why do plants wilt when too much fertilizer is put on the soil?

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words on your answer sheet which should be substituted for the italicized ones to make the statement true.

1. A *clay* soil is one of the best soils for growing plants.
2. Any materials found in a soil that were produced by living things are called *organic* materials.
3. Good crop yields are sometimes obtained in dry climates by *irrigation.*
4. It takes two years to produce *corn.*

PROBLEM 3. How can plants that affect other plants be controlled?

HELPFUL AND HARMFUL PLANTS

Plants that aid other plants. Some plants aid other plants by supplying conditions and materials necessary for growth. Bacteria growing on the roots of certain plants such as peas, alfalfa, and clover produce chemical compounds containing nitrogen obtained from the air. From these compounds, green plants get the nitrogen which they cannot use from the air. Other kinds of fungi that often grow on the roots of oak trees decompose the organic material in the soil around the roots so that its chemical elements are available to the tree. They may also assist the roots of the tree in obtaining water from the soil. Certain soil bacteria also break down organic matter in the soil, making its elements available to plants.

Some plants cannot grow in direct sunlight and depend upon other plants for shade. The trees and tall shrubs in this wooded area shade the ferns and other plants.

Soil Conservation Service

We have already seen how bacteria may be placed on the seeds of peas and clover before the seeds are planted (see page 364). The bacteria will thus be present when seeds germinate and will develop on the roots of the young seedling.

Plants that harm other plants. There are many plants harmful to those man tries to raise. Some, such as bacteria, *rusts,* and *smuts,* cause plant diseases. Others remove materials from the soil essential for the growth of the crops. Still others grow so tall that they keep necessary light away from the crops.

Protection from weeds. *Weeds,* plants growing where they are not wanted, remove from the soil moisture and mineral elements needed by desirable plants, and compete with them for light. One of the most effective methods of controlling weeds is to kill them before they produce seed by hoeing, plowing, treating them with chemicals, or burning them. Some weed-killers have been used to kill broad-leaf weeds in lawns without permanently damaging the grass. Directions for mixing and applying chemical weed killers should be carefully followed to avoid killing valuable plants.

When grass, clover, and other small seed are harvested, large quantities of weed seed are harvested with them unless special precautions are taken. Seed producers are required by law to indicate the amount of weed seed in the seeds they sell. Seeds are inspected by government seed inspectors to be sure that the label is accurate.

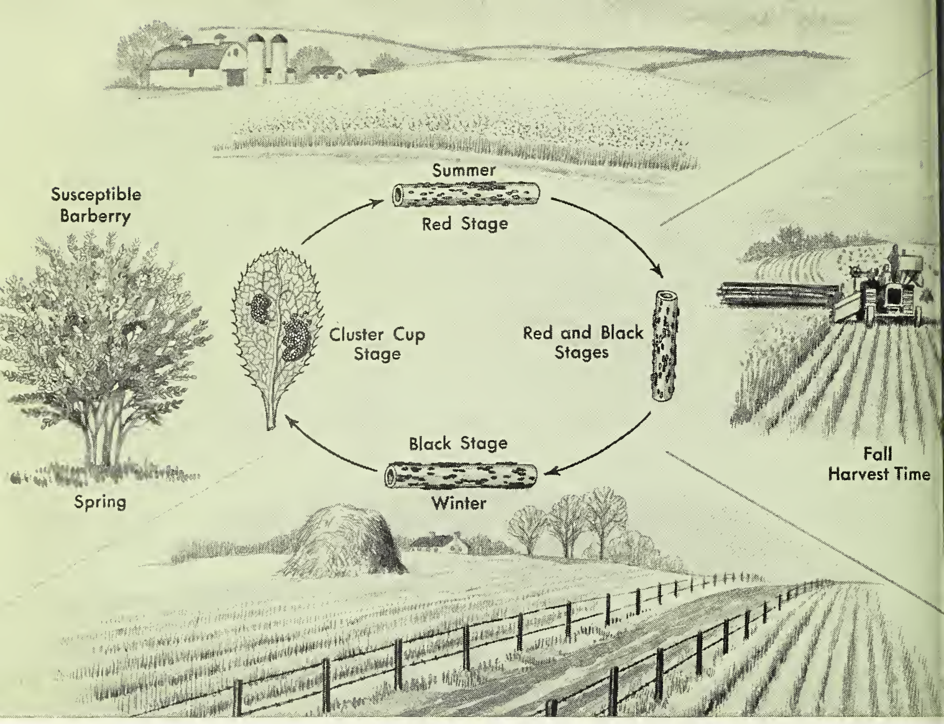
CONTROLLING HARMFUL PLANTS

Protection from bacteria. One of the big problems in growing crops is protecting the crops from diseases known as *rots* and *wilts* caused by harmful bacteria. The bacteria may enter the plant through natural openings, such as the stomata, or through broken places in the outer covering of the plant. They are also carried by insects from one plant to others upon which the insects feed. Once harmful bacteria have entered the plant, they may destroy plant tissue, thus causing parts of the plant to rot. If the bacteria get into the water-conducting tubes, they obstruct the flow of water through the plant, thus causing it to wilt. Once bacteria have entered the plant, little can be done to control them. Generally the infected parts of the plant must be removed and burned. Therefore plants subject to rots and wilts should be protected from disease-carrying insects.

Protection from mildews, rusts, and smuts. Fungi, such as *powdery mildews,* rusts, and smuts, cause great damage to farm crops. These fungi differ from bacteria in that each individual fungus is made up of a large number of cells, whereas bacteria are single-celled plants.

The powdery mildews cause many diseases among such plants as rose and gooseberry, and apple, cherry, and ash trees. The mildews are propagated by spores, which are microscopic in size and easily carried from one plant to another through the air. The spores of powdery mildew generally start growing on the leaves, producing rootlike structures which pierce the leaves and absorb food from leaf cells. The strands of the fungus that grow over the surface of the leaf then produce millions of spores which appear as a powdery substance on the leaves.

Any substance used in killing fungi



The stem rust of wheat, oats, barley, and rye passes through four stages in its life cycle. It is the red stage in summer that damages grain crops. If common barberry plants are destroyed, the cluster cup stage cannot occur, thus controlling the rust.

is called a *fungicide*. Powdery mildews may be destroyed by a fungicide made of a sulfur solution which is sprayed on the plants. Other fungicides, such as *Bordeaux mixture,* are sprayed upon plants to prevent the mildew from infecting them. Bordeaux mixture, made up of lime and copper sulfate in water, is one of the most commonly used fungicides.

The stem rust of wheat is a fungus that causes millions of dollars' worth of damage to wheat crops each year. It is a parasite depending upon the wheat plant for food. As shown above, the stem rust of wheat goes through several different stages in completing its life cycle, and is controlled by removing common barberry bushes.

Corn and wheat smuts develop much like other fungi. In order to control smuts, the seeds before being planted are treated with chemical fungicides, like formaldehyde, killing smut spores.

Detectives of plant diseases. Failure to identify and check plant diseases introduced from other countries has resulted in two disastrous outbreaks of plant diseases. The chestnut-blight fungus was probably introduced from Japan about 1900. Since that time it has spread throughout the United States and killed practically all the

American chestnut trees. The Dutch elm-disease fungus, which arrived from Europe about 1930, is rapidly killing American elm trees.

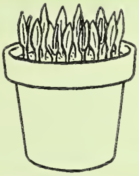
Specialists in plant diseases have reported the existence of disease-producing organisms that could destroy entire fields of crops in a very short time if they were distributed when weather conditions were favorable for their development. In 1943 an organization called the Plant Disease Survey stationed scientists throughout the country where they worked as *plant-disease detectives.* Over 150 plant diseases were found for the first time in states where they had not previously been known to occur. Since our annual crop losses from diseases cost us millions of dollars each year, it would seem that some national defense against plant diseases would be desirable.

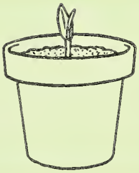
Because of the diseases they may introduce, the shipment of certain plants from foreign countries into the United States is prohibited. Some states, such as Arizona and California, have enacted laws to regulate the shipment into those states of plants that might be diseased. At checking stations set up on highways entering the states, all cars are inspected to make sure that neither fruit nor plants of any kind are brought into the state.

SUMMARY

Plants which produce materials or conditions favorable to the growth of desirable plants are considered beneficial. On the other hand, those which damage the tissue of desirable plants or deprive desirable plants of the materials essential to growth are considered harmful. Beneficial plants are encouraged by being provided with favorable environmental conditions. Harmful plants are destroyed when the environmental conditions are changed so that they cannot grow or reproduce.

EXPERIMENT





Question to be answered. What effect does thinning have upon plant growth?

What you need. Two pots of the same soil; 24 corn seeds; water; ruler.

What to do. Plant 12 seeds in each pot, and set them in a well-lighted part of the room. Water them daily, being sure to give each pot the same amount of water. After the corn plants are about 2 inches tall, pull out all but one plant near the center of one of the pots. Do not remove any of the plants from the second pot. Be sure that each pot gets the same amount of light and water. Measure the height of the corn plants in each pot every two or three days.

Your answer. Why was each pot given the same amount of light and water? What was the one difference between the two pots of plants? In which pot did the plants grow best? Write a sentence that answers the experimental question.

Assumptions in this experiment. 1. All plants would act the same way as these plants.

2. Plants growing outdoors would act the same as these plants.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The bacteria on the roots of plants such as peas and clover aid other plants by (a) adding usable nitrogen to the soil; (b) keeping weeds from growing; (c) increasing the water content of the soil; (d) adding phosphorus to the soil.
2. Plant diseases known as rots and wilts are caused by (a) too much water; (b) too much sunshine; (c) bacteria; (d) lack of minerals in the soil.
3. Powdery mildews on plants can be controlled by (a) watering the plant more often; (b) treating the soil at the base of the plant; (c) spraying the plant with water; (d) spraying the plant with fungicide.
4. The common barberry is destroyed to prevent (a) corn smut; (b) powdery mildews; (c) wheat rust; (d) wheat smut.

PROBLEM 4. How can animals that affect plants be controlled?

CONTROL OF INSECTS

Although some animals are harmful to plants, others help plants. Small animals, such as earthworms, burrow holes into the soil and make it possible for more air and water to enter the soil. As shown on page 397, all animals give off carbon dioxide that is used by plants in manufacturing food. Solid and liquid wastes (organic matter) given off by animals contain nitrogen and other elements essential to plants.

Insects, such as bees, help pollinate flowers, as shown on page 398. As you will see later, birds also help protect plants from insects.

Harmful insects. It has been estimated that insects damage or destroy one tenth of the farm crops produced in this country each year. Almost as many trees are destroyed by insects each year as are burned by forest fires.

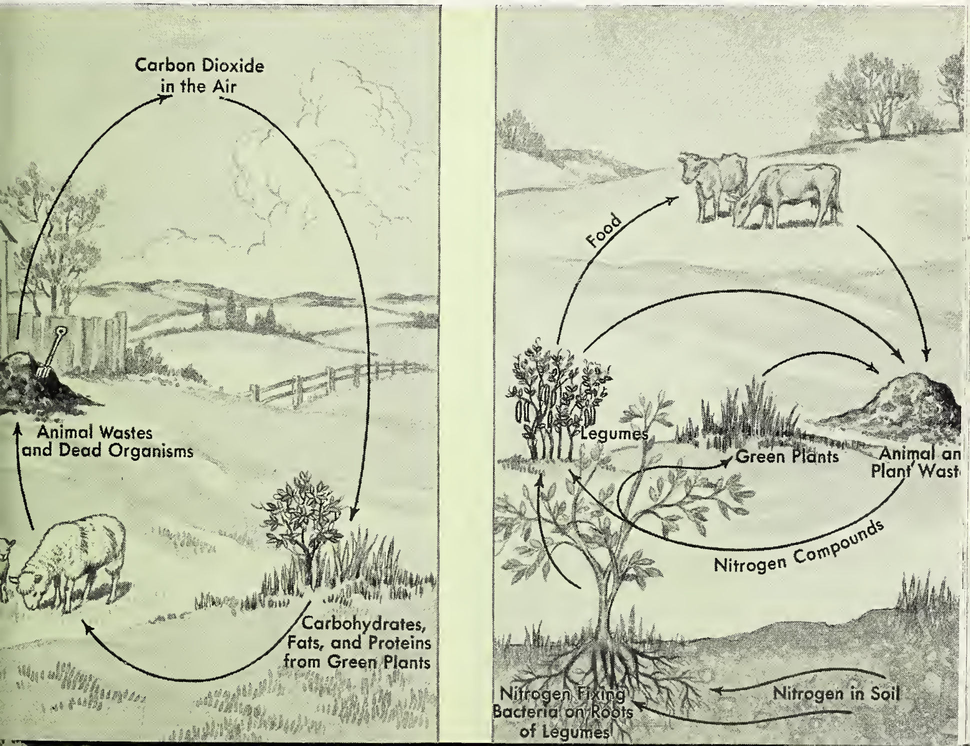
Insects damage plants in different ways. Some insects, such as the grasshopper, have chewing mouth parts and eat the leaves, buds, bark, roots, stems, and fruits of plants. Others, such as aphids, cannot chew but suck juices from plants. Plants weakened from attacks by insects may become stunted or deformed, or may die.

Control of insects by poisons. Generally those insects that eat plants can be controlled if the plant is sprayed with poisonous chemicals. The gypsy moth is an example of such an insect. The female moth often lays her eggs on the leaves of apple trees. When the eggs hatch, the larvae or *caterpillars* eat the young leaves of the apple tree, causing serious damage to the tree. In order to protect the tree, *lead arsenate* is sprayed upon the leaves in the early spring when the eggs are hatching. Lead arsenate is poisonous and kills the insects when they eat the leaves.

As shown on page 398, grasshoppers may cause the complete loss of a crop by eating practically all the plant. They can be killed by being supplied with food mixed with a poison. Such poisons, which kill the insect when it eats it, are called *stomach poisons.*

Insects that suck juices from plants cannot be controlled by stomach poisons. Sprays containing a mixture of soap, water, and nicotine sulfate have been used in controlling some sucking insects, such as the *aphid,* which dies when the nicotine sulfate comes in contact with its body. Such a poison is called *contact poison.*

In the carbon cycle (left), carbon dioxide given off by animals is used by plants in photosynthesis to make food. In the nitrogen cycle (right), nitrogen compounds from wastes and from bacteria on roots of legumes are used by plants to make food which may be eaten by animals.


Carbon Dioxide in the Air
Animal Wastes and Dead Organisms
Carbohydrates, Fats, and Proteins from Green Plants
Food
Legumes
Green Plants
Animal an Plant Wast
Nitrogen Compounds
Nitrogen Fixing Bacteria on Roots of Legumes
Nitrogen in Soil

Bureau of Entomology and Plant Quarantine

As the bumblebee in this picture seeks food from the flower, pollen becomes attached to its body and is carried to other flowers.

Insect traps. Some insects, such as the chinch bug and the Japanese beetle, may be trapped. Chinch bugs cause great damage to wheat each year. They frequently move in large numbers from one field to another. The mass movement, or migration, of chinch bugs may be controlled by trenches dug across the path of their movement. Into holes at regular intervals along the trench, creosote is poured. The chinch bugs fall into the trench and crawl around the bottom of the trench until they fall into one of the holes, where the poisonous creosote kills them.

Grasshoppers such as the one shown in the upper corner have destroyed this field of corn.

Bureau of Entomology and Plant Quarantine

Japanese beetles cause great damage to more than 200 different plants by eating their leaves. Traps used in an attempt to control the Japanese beetle consist of a glass jar over which is fitted a metal cover. The beetle can enter but cannot escape.

Natural enemies. Insects have a number of natural enemies, including birds, frogs, and skunks, as well as other insects. Woodpeckers and creepers remove insects from the bark of trees, quail scratch them out of the ground, and flycatchers and swallows catch them in the air. Frogs, toads, snakes, and some mammals also feed upon insects. An insect called the ichneumon fly, lays its eggs in the larvae of wood-boring insects. When the young hatch, they consume the larvae of the destructive insects. Blister beetles eat grasshopper eggs. The praying mantis destroys several different insects including grasshoppers. The ladybird beetle was brought to America from Australia to control the *cottony-cushion scale,* a serious pest of the citrus orchards in California. Today ladybird beetles are collected and distributed to citrus growers for use in controlling cottony-cushion scale.

Insects are also subject to diseases caused by fungi. Scientists have used several different types in attempts to control insects that are undesirable.

OTHER HARMFUL ANIMALS

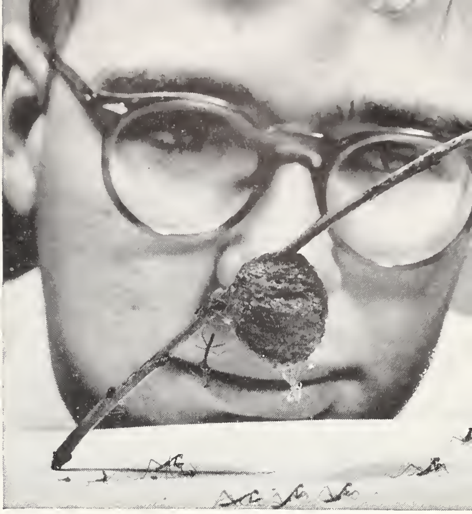
Protection of plants from birds. Some birds, such as the pheasant and wild duck, become harmful pests at times. In the early spring before there are many insects for them to feed upon, the pheasants may dig up the seed grain farmers have planted or eat the young plants. Wild ducks may also destroy grain, such as corn or rice, after it has ripened in the field. Both pheasant and wild ducks are protected by laws that prohibit killing them except during limited periods. Whenever these game birds become so numerous that they are serious pests, the hunting season is generally extended.

Protection of plants from rodents. *Rodents* are small mammals, such as gophers, ground squirrels, prairie dogs, rats, rabbits, and beavers, which may do serious damage to farm crops, trees, and stored grain. Gophers, ground squirrels, and prairie dogs make their homes in *burrows,* or tunnels, in the ground and live upon plants. They destroy seed grain, young crop plants, grass, and roots of fruit trees. In grain-growing states, such as Iowa, Minnesota, and the Dakotas, and in the grasslands of the western states, these rodents have become serious pests. They have increased in large numbers because many of their natural enemies, such as hawks, foxes, and wolves, have been killed.

Rodents are poisoned in a number of ways. One effective method of poisoning gophers is to suffocate them with a chemical called *carbon bisulfide*. A rag soaked in carbon bisulfide is placed in the burrow. The openings to the burrow are then covered with soil so that the poisonous fumes will pass into all parts of the burrow, killing the gophers. Poisoned baits are often used in controlling prairie dogs and ground squirrels.

So many beneficial birds have been killed from eating poisonous baits intended for rodents that scientists have attempted to produce substances poisonous only to rodents. Red squill has proved to be an effective rat poison which will not kill other animals. Scientists have also discovered that some birds will generally not eat poisoned foods when colored green or yellow.

Protection from large mammals. In some sections of the country, large mammals, such as deer and elk, may destroy crops. There are two main reasons why these animals have increased in such numbers that they have become pests. First, it is illegal to kill them except during certain seasons. Second,



Courtesy Life Magazine

Praying mantises drop from the sac in which they hatch and walk away. From each sac come enough insects to control pests on a quarter acre. The mantes never destroy leaves, but only harmful pests.

many of their natural enemies have been destroyed. Therefore, the most effective ways to control large mammals is to extend the hunting season and to protect their natural enemies.

Fences are sometimes used in an attempt to keep deer and elk out of hayfields, but they are not always effective. After heavy snows in the mountainous regions of Colorado, it is not uncommon to see bull elk feeding on top of a haystack with wire from the fence which had enclosed the haystack hanging on their antlers. Farmers and livestockmen are usually not allowed to kill deer and elk except during a regular hunting season. However, they may be able to obtain payment from the wild-game authorities of their state for damages these animals have caused to their crops or feed.

SUMMARY

In order to control an insect effectively, it is necessary to know its life history and the manner in which it obtains food. Encouragement of natural enemies, traps, and poisons are the most common methods of controlling insects. Care should be taken to prevent the method of control from destroying beneficial types of animals.

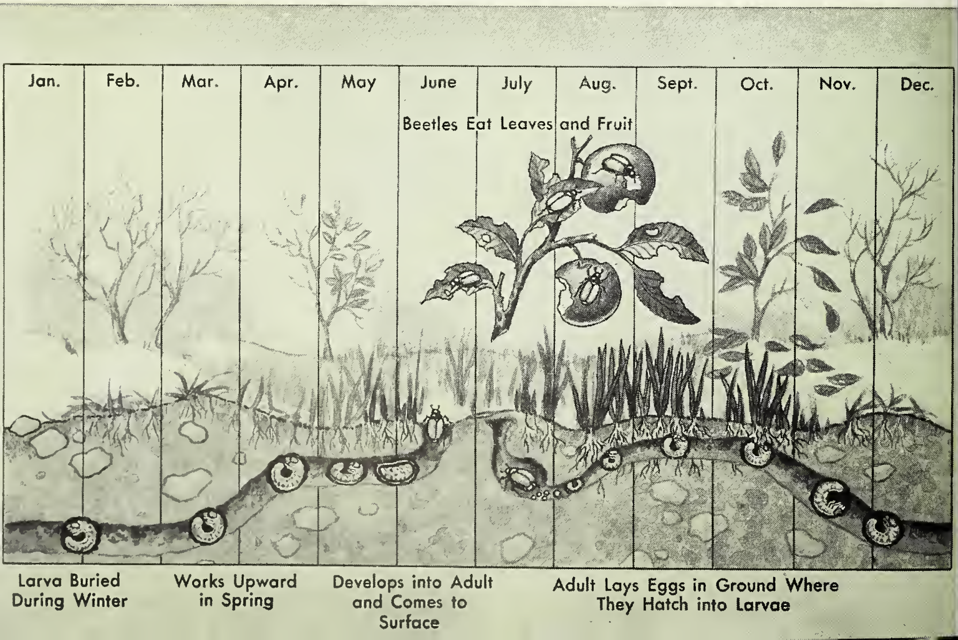
Many of the methods used in controlling insects can also be used to control other small animals that destroy desirable plants.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words on your answer sheet which should be substituted for the *italicized* ones to make the statement true.

1. Earthworms are *harmful* to the soil.
2. An insect which sucks juices from a plant can often be killed with a *stomach poison.*

Life cycle of the Japanese beetle. Notice that eggs hatch in August.


Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Beetles Eat Leaves and Fruit
Larva Buried During Winter
Works Upward in Spring
Develops into Adult and Comes to Surface
Adult Lays Eggs in Ground Where They Hatch into Larvae

3. Some insects are *harmful* to plants because they carry pollen from one flower to another.
4. Ladybird beetles are propagated and distributed to help control the *cottony-cushion scale*.
5. *Red squill* is a rat poison that will not kill other animals.

CHAPTER ACTIVITIES

REVIEW HOW TO CARE FOR PLANTS

Six conditions desirable for good plant growth are listed below, followed by a list of a number of man's activities designed to aid plant growth. Select the condition that is aided by each activity, and write its number beside the letter of the activity in the proper place on your answer sheet. **Do not write in your textbook.**

CONDITIONS FOR GOOD PLANT GROWTH

1. The proper amount of soil moisture
2. Soil containing adequate minerals
3. Suitable temperature
4. Proper amount and strength of light
5. Protection from other plants
6. Protection from animals

ACTIVITIES OF MAN DESIGNED TO AID PLANT GROWTH

a. Cultivating the soil with a hoe in a weed-free garden
b. Destroying common barberry plants
c. Irrigating the land
d. Spraying plants with a contact poison
e. Adding organic matter to the soil
f. Operating smudge pots in citrus orchards
g. Shading young plants from direct sunlight

CAN YOU THINK SCIENTIFICALLY?

After the 1947 rice harvest in Japan, it was claimed that production of rice around Hiroshima was much greater than before the atomic bomb had been dropped on that city. It was reported in the newspapers that the atomic bomb had caused substances in the soil to become radioactive. The radioactive materials were believed, therefore, to have caused the increased yield of rice on farms around Hiroshima.

On your answer sheet, write the number of each statement or question listed below that would have been made or asked by a person who was thinking scientifically.

1. There is no connection between the atomic bomb and increased rice production.

2. Merely because increased rice production followed the destruction of Hiroshima by the atomic bomb does not necessarily mean that there is any connection between the two incidents.

3. There may have been other conditions causing the increased production.

4. Tests should be conducted under controlled conditions to check the effects of radioactive substances upon the production of rice and other crops.

5. Was any new land used for rice fields?

6. The report is interesting although more data are needed before a final conclusion can be made.

U.S. Department of Agriculture

Spraying animals with chemicals to protect them from harmful insects. This is one of the ways in which we care for animals.

chapter 21 CARING FOR ANIMALS

WILD animals in their natural environment are usually able to care for themselves as long as we do not disturb them. They are free to secure food, water, and shelter. Most of them possess ways of protecting themselves from their natural enemies. They usually produce sufficient offspring to replace the older animals as they die. But when man removes animals from their natural environment or changes their environment, it becomes necessary to provide special care for them.

PROBLEM 1. How are animals supplied with food?

FOOD-GETTING AND DIGESTION

Uses that animals make of food. One of man's most important problems in raising animals is to provide them with food and water. Food and water serve the same purposes for animals that they do for us. Animals use food to obtain the energy needed to carry on their body processes and to do required work. They also need food to build body materials such as muscles, bones, hides, hair, milk, and eggs.

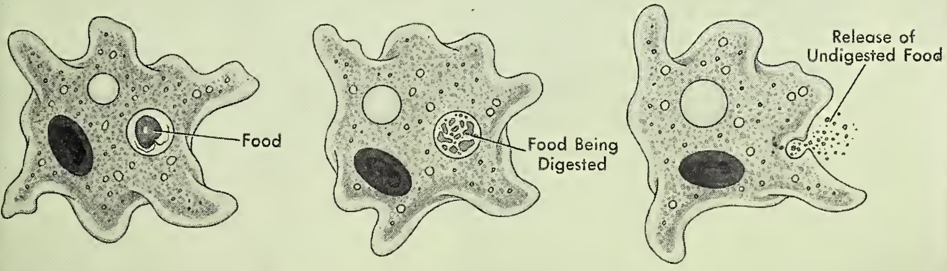
Digestion of foods. Animals, like man, must digest their food before it can be used to produce energy and build body tissue. The way the simplest type of animal, the one-celled *ameba,* digests food is shown below. In many animals food is digested in a long tube called the *digestive tract,* which extends through the animal's body. We have already seen how the mouth, esophagus, stomach, and intestines make up our digestive tracts. Similar structures are found in many other animals.

Food grasping and grinding. The digestive tract of animals generally begins with some special structure for seizing or picking up food. The horse uses its upper lip and heavy front teeth, called *incisors,* for seizing food. The cow grasps food with its tongue and lower teeth since it has no upper front teeth. Chickens, turkeys, and ducks pick up their food with their toothless beaks. Dogs have sharp side teeth, called *canine* teeth, for tearing their food. Rodents have chisel-shaped front teeth for gnawing their food.

Most mammals prepare their food for digestion by grinding it between heavy teeth, called *molars,* in the back of their mouths. Dogs and cats chew their food very little before swallowing it. Such mammals as cattle and sheep (*ruminants*) also swallow their food before it is thoroughly chewed. The partly chewed food passes into a temporary storage stomach, from which it is later forced back into the mouth, and chewed more thoroughly. It is thus possible for a cow to take a large amount of food in a short time and then chew it later.

The animal's stomach and intestines. After the animal has eaten, the food is changed into simpler materials by chemical substances in the digestive tract. In most domesticated animals

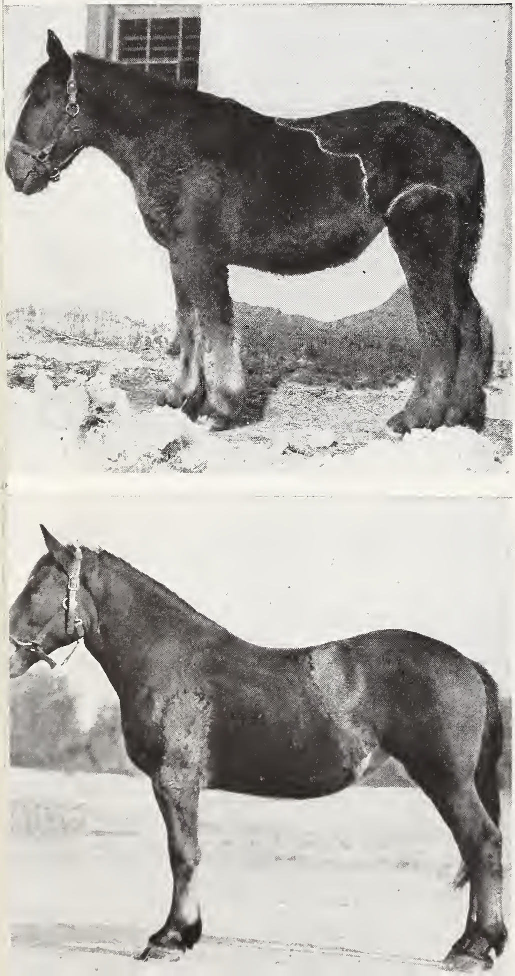
The way in which one of the simplest forms of animals, the ameba, digests its food and releases wastes.



the digestion of food generally begins in the stomach. Some mammals, such as cattle and sheep, have four stomachs; others have only one. The horse's stomach is so small that the food remains in it only for a short time before it is forced into the small intestine.

The young horse above is suffering from a lack of vitamin A. Note its poor posture and rough coat. The white lines mark portions of scaly skin. The picture below is the same horse after it had been fed properly and treated for vitamin A deficiency. Scaly coat is now smooth.

U.S. Department of Agriculture



Chickens and other fowl swallow their food whole and store it temporarily in a structure called the *crop*. It then passes into one stomach where it is mixed with digestive juices, then into another heavily muscled stomach called the *gizzard,* where it is ground and crushed.

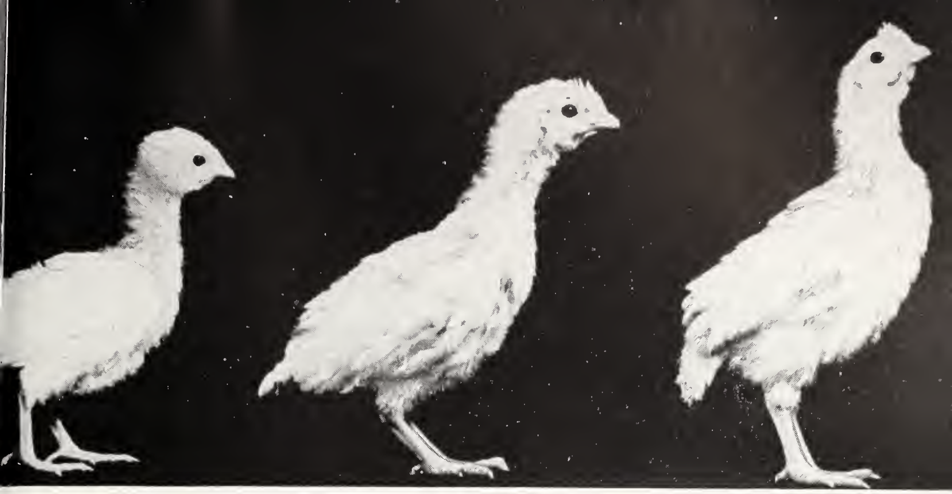
In these animals, as in man, the digestion of food is completed in the small intestine. It is then absorbed and carried by the blood to cells of the animal's body.

FOOD FOR ANIMALS

A balanced ration. The food that is fed to animals is called a *ration.* A ration that contains the right quantity of digestible protein for tissue building and the right quantity of carbohydrate and fat for the energy needs of the animal is called a *balanced ration.*

Different animals require different quantities of carbohydrates and proteins. Dairy cows need both grain and hay; beef cattle need grain, such as corn, to fatten them. Idle horses are fed plenty of roughage, such as hay, but work horses need more energy foods like grain. Colts and calves need more minerals and proteins than older animals in order to build bone and body tissue.

Based upon their weight, hens need more proteins than any other domestic animal, and they can get it from meat scrap, skim milk, and buttermilk. Extra calcium to produce the shells for eggs is supplied in such foods as bone meal. As much as half of the ration for dogs and cats should be meat. The dog needs in addition broth, eggs, tomato juice, spinach, carrots, and milk; the cat gets liver and fish as well as vegetables.



Merck & Co., Inc.

The chick at left, fed only a basal ration, weighed 126 grams after three weeks; the center chick, fed ration and some vitamin B_{12}, weighed 186 grams; the one at right, fed ration, B_{12}, and an antibiotic, weighed 218 grams. This shows the dramatic growth-stimulating qualities of antibiotics.

Animals need vitamins and minerals for the same purpose that we do.

Preparing and storing food for animals. To provide animals with balanced rations is one of man's concerns. He uses pastures of grass, clover, or alfalfa for feeding horses, cattle, sheep, hogs, and chickens. Throughout the Southwest cattle, sheep, and horses are raised on natural grasslands, called *ranges*. Since grass and hay cannot be grown the year around, hay is preserved for winter use by being dried after it is cut. It may then be piled into large stacks, pressed into bales, or ground into a fine meal and stored in sacks.

Ripe grains, such as corn, oats, and barley, can be stored in specially constructed buildings called *granaries*. To preserve green corn for animal feed, the entire plant is cut into small pieces and packed into pits or tall structures, called *silos*. Chemical substances produced as a result of fermentation by yeasts and bacteria preserve the corn. Corn and other green crops which are preserved this way are called *silage*.

By-products of manufacturing processes, like the pulp left after the sugar has been extracted from sugar beets, are used as animal feeds. Meals made from cottonseed and flaxseed (linseed) supply animals with additional protein. Slaughterhouse waste materials, such as blood, lungs, intestines, and tendons, are processed and sold as *tankage,* a valuable food for cattle and hogs and chickens, rich in animal protein.

Feeding antibiotics. It has been found that feeding small amounts of certain antibiotics such as, aureomycin, penicillin, and terramycin, will cause chickens, turkeys, and hogs to grow faster on less food. Experiments have shown that without antibiotics, it took 825 pounds of feed to produce a 225-pound hog. With terramycin in the ration, it took only 700 pounds.

SUMMARY

Animals possess body structures used especially for obtaining food and preparing it for use in their body cells. The food needs of an animal are determined by its size, age, and the nature of its physical activity, as well as by the kinds of products it is expected to produce. In order that animals may obtain the nutrients essential for proper growth and development, both plant and animal products are used as food.

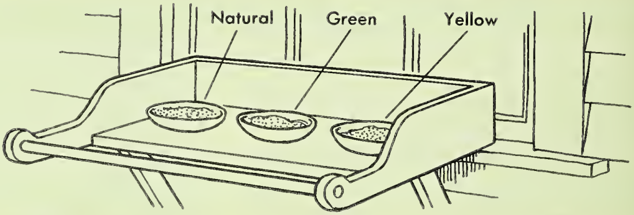
OBSERVATION

What to observe. The gizzard of a chicken.

How to observe it. Obtain a gizzard from a freshly killed chicken. Cut the gizzard open and examine its contents.

Interpretation of your observation. What kind of tissue makes up most of the gizzard? Did you find grit? For what is it used? How is the gizzard attached to the rest of the digestive tract?

EXPERIMENT



Question to be answered. Does cracked wheat that has been colored have less appeal to birds than natural coloring?

What you need. A bird-feeding station outside of one of the windows of your classroom; two pounds of cracked wheat; green and yellow vegetable coloring.

What to do. Put out cracked wheat in your bird-feeding station until the birds become accustomed to it and are eating it regularly. Color about a quarter of a pound of cracked wheat green and another quarter of a pound yellow by dipping it into the vegetable coloring. After the colored wheat has dried, weigh out equal portions of green, yellow, and natural wheat, and put in separate containers. Leave on the feeding station for one day, and weigh each of them again.

Your answer. If you had an opportunity to observe the birds while they were feeding, did you note that they ate from one container more than another? In terms of weight loss, from which container was most food taken? You may want to try this on several occasions before you make a final conclusion. Be sure to check your assumptions.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words on your answer sheet which should be substituted for the italicized ones to make the statement true.

1. Cattle and sheep have *four* stomachs.
2. When an animal's ration contains the right amount of digestible protein, carbohydrates, and fat, it is a *balanced* ration.
3. Green crops preserved in pits or silos by fermentation are called *tankage*.
4. As much as *one half* a dog's or cat's ration may be meat.
5. Based upon their weight, *pigs* need more protein than any other animal needs.

PROBLEM 2. How are animals protected from harmful organisms?

PROTECTION AGAINST PLANTS

Harmful plants. If milk cows eat the white snake plant, they develop a fever and their milk becomes poisonous to persons drinking it. On the western ranges there is a plant called the *locoweed* (crazy weed), which affects the nervous systems of horses when they eat it. They lose control of their actions, and death soon follows. Other plants, such as monkshood, arrow grass, death camass, and larkspur, are poisonous to livestock. Livestockmen protect their animals by removing the poisonous plants from the range or pasture. They also try to maintain enough grass so that cattle, horses, and sheep will obtain sufficient food from the grass and will therefore not eat the poisonous plants.

Some plants, such as sandburs and needle grass, produce seed with sharp spines or projections on them. If animals eat grass containing such plants, the sharp spines may enter the tongue and other parts of the mouth, causing inflammation and resulting in infection. Most of such plants are eaten by animals when more desirable types of food are not available.

PROTECTION AGAINST GERMS

Disease-producing germs. Some of the more common animal diseases, the organisms causing them, and the effect on the animal's body are listed in the table on page 409.

To control germs which cause diseases in animals, it is necessary first to determine the kind of organism causing the disease, then to find out how the organism enters the body of the animal. Finally, it is important to know how the animal's body naturally protects itself from the organism. With these three kinds of information it has been possible to develop ways of protecting animals from some of the diseases which attack them.

Animals may produce antibodies

U.S. Department of Agriculture

These men are vaccinating a young pig for hog cholera. Immunizing animals in this manner has greatly reduced the number of animals lost by this disease.

which help protect them from certain disease germs (see page 344). Animals can therefore be immunized to such diseases as cholera, anthrax, and tetanus in the same way humans are immunized, as shown above.

Both sulfa drugs and antibiotics have also been used to control several different disease-producing germs after they get into the animal's body.

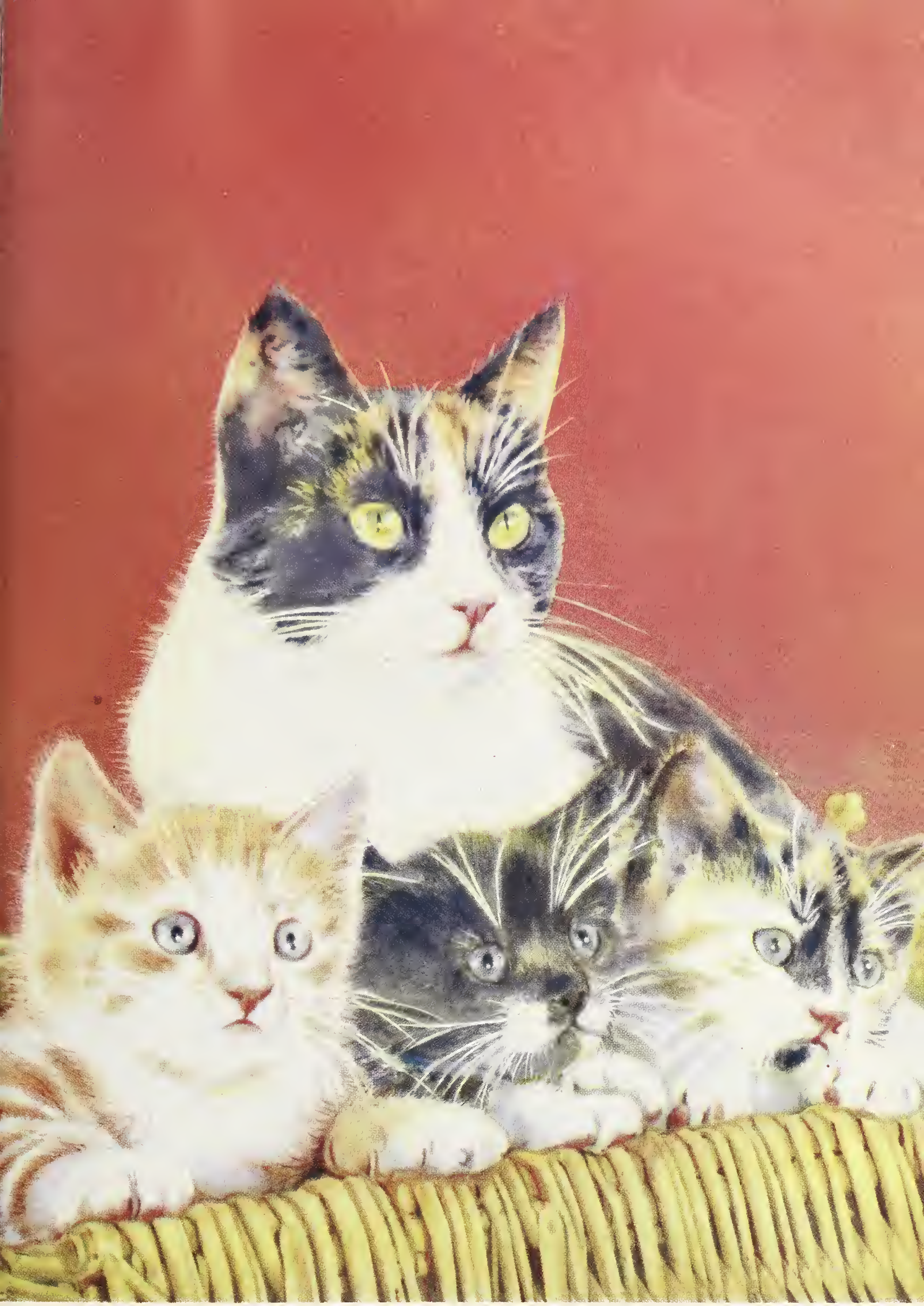
OTHER PROTECTIONS

Animal parasites. Practically every animal is a *host* to parasites of some kind. Some parasites have no ill effects. However, others may slow down the growth of their host, lower its resistance to disease, and even kill it. Parasites can damage the hide, meat, intestines, and livers of their hosts. The harmful parasites of animals include flies, ticks, mites, lice, and worms.

From experiments conducted by the United States Department of Agriculture, it has been proved that better products in greater quantities can be obtained from animals properly treated for parasites. Animals may be sprayed with chemical substances such as DDT that kill the pests on them, or they may be dipped into chemical solutions (see page 402).

Various kinds of worms live as parasites in the stomach or intestines of many animals where they do great damage. Some parasitic worms damage the walls of the stomach or intestines, thus causing the animal to become weak and sick.

The eggs of parasitic worms are passed from the animal's body, and get onto food eaten by other animals. One way to prevent animals from becoming thus infected is to keep the animals' pens clean. However, if an



John and Cossie Mechling, F. P. G.

Heredity accounts for both likenesses and differences between parents and offspring. As you will note in this picture, none of the kittens looks exactly like the mother, although two of them have some of her characteristic markings.

Monkmeyer Press Photo Service

By cross breeding, plant scientists have developed the Delicious type apple with a warm golden skin as well as with a red skin flecked with white.

animal does become infected with worms, certain chemicals can be used to get rid of the worms. The chemicals may be given to animals with their food or directly through the mouth in little containers called *capsules*.

Predatory animals. Animals such as hawks, coyotes, and mountain lions may kill livestock for food. They are called *predatory* animals. Under natural conditions, they kill other wild animals for food. But when man destroys their natural food supply, they may kill livestock. Coyotes naturally depend upon rabbits for food, but man has killed so many rabbits that coyotes often kill chickens. The mountain lion depends upon deer, but when deer become scarce, it often kills young calves. Whenever predatory animals become pests, they are often killed in large numbers. Such mass destruction is usu-

SOME DISEASES OF ANIMALS CAUSED BY LIVING ORGANISMS

DISEASE AND ORGANISM CAUSING IT	ANIMALS COMMONLY AFFECTED	EFFECT UPON THE ANIMAL
Tuberculosis (Bacterium)	Cattle, hogs, fowl, birds, fish, reptiles	Destroys lung tissue
Diphtheria (Bacterium)	Cattle, dogs, cats, horses, fowl, rabbits, guinea pigs	Forms false membrane in throat and produces poisons
Anthrax (Bacterium)	Cattle, hogs, sheep, goats, horses	Blood darkens and thickens, spleen enlarges, causes rupture of blood vessels in the body
Tetanus (Bacterium)	Cattle, mice, horses, guinea pigs, rabbits, goats	Damages nervous tissue and causes paralysis of jaws and generalized rigidity
Pneumonia (Bacterium)	Dogs, cattle, rabbits, mice	Lungs fill with fluid
Sleeping Sickness (Protozoan)	Horses	Paralysis of muscles
Texas Cattle Fever (Protozoan)	Cattle, horses, sheep, monkeys, dogs, rats, rodents	High fever, splenic enlargement, inflammation of stomach, damages red blood cells
Hydrophobia (Virus)	Dogs, cats, wolves, skunks	Paralysis of extremities, convulsions, smothering
Cowpox (Virus)	Cattle	Skin lesions, pustules
Cholera (Bacterium)	Hogs and chickens	Diarrhea and collapse, skin turns a purplish blue, animal is crippled
Foot-and-Mouth Disease (Virus)	Cattle, pigs, goats, sheep	Eruptions of vesicles in mucous membranes and formation of ulcerous sores, pustules, fever, and painful swallowing

ally followed by an increase of the animals of which the *predator* was a natural enemy.

SUMMARY

A number of living things are harmful to those animals which man raises. Many of them harm the animal by producing poisonous substances. Some do harm by destroying or damaging parts of the animal's body, whereas predators attack and kill the animal.

Animals are protected from other living things in two important ways. The environment of animals may be controlled so that the other living things are destroyed before they can cause harm. If harmful organisms do enter the animal's body, they may be controlled by the use of chemical substances which kill the offenders or otherwise cause them to be harmless.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words on your answer sheet which should be substituted for the italicized ones to make the statement true.

1. If horses eat a plant called the *locoweed,* their nervous systems are affected and death may soon follow.
2. Many insect pests of animals can be killed by spraying the animals with *2,4-D.*
3. Animals that kill livestock for food are known as *predatory* animals.
4. Animals can be immunized against *cholera.*

PROBLEM 3. In what other ways are animals cared for?

HOUSING ANIMALS

Shelters for livestock. It has been demonstrated that dairy cattle kept in clean, well-ventilated barns where temperatures are controlled will produce more milk than dairy cattle not protected in this manner. An excellent barn is shown in the picture on page 412. To obtain the largest egg production, hens must be kept in clean, well-lighted chicken houses where even temperatures can be maintained.

Shelters for pets. The proper housing of pets is very important in maintaining healthy animals. Out-of-doors is generally the best place for a dog, if a suitable doghouse has been provided. Doghouses should be warm, protected from rain and wind, and well ventilated. If kept in the house, the dog should have a basket or bed in a part of the house protected from drafts.

Some people keep canaries as pets. Canaries should be kept in cages closed on one side to prevent drafts. The cage should never be hung in a window or in the middle of a room.

An aquarium for fish. Raising fish as house pets probably presents more problems than raising any other animal. Fish are kept in a water-filled container called an *aquarium.* By using their *gills,* fish obtain the oxygen they need from that which is dissolved in water. Although most oxygen enters the water from the air, additional oxygen may be provided by growing green plants in the aquarium (see page 40). Fish give off carbon dioxide as a waste product which can in turn be used by the plants in manufacturing food.

Some kinds of fish live upon plant foods, whereas others must have animal foods such as meat. It is important to remember that excess food and wastes given off by fish should be removed from the water. Snails may be kept in an aquarium to help remove waste materials.

CARING FOR ANIMALS

Improving the appearance. Most people are proud of the animals they raise, and they do many things to improve their appearance. The coats of animals, such as horses, dairy cows, and dogs, are generally cleaned at regular intervals. The cleaning is usually done by combing and brushing the hair, and sometimes by using soap and water to remove dirt that cannot be combed out. Dairy cattle are usually cleaned in this manner before each milking to prevent dirt from dropping into the milk. Dogs may be bathed occasionally with warm water and mild soap, but cats should never be bathed.

Comfort and cleanliness. The feet of some animals are given special care. Horses' feet are generally protected from wear by horseshoes, nailed on the bottom of their hoofs. Before the horseshoes are attached, the horny material on the bottom of the hoof is trimmed evenly so that the animal can walk comfortably. Occasionally the hoofs of cattle become crooked and have to be trimmed so that they can walk and stand properly. The claws of bird pets sometimes have to be trimmed when they become so long that it is not possible for the birds to sit comfortably on their perches.

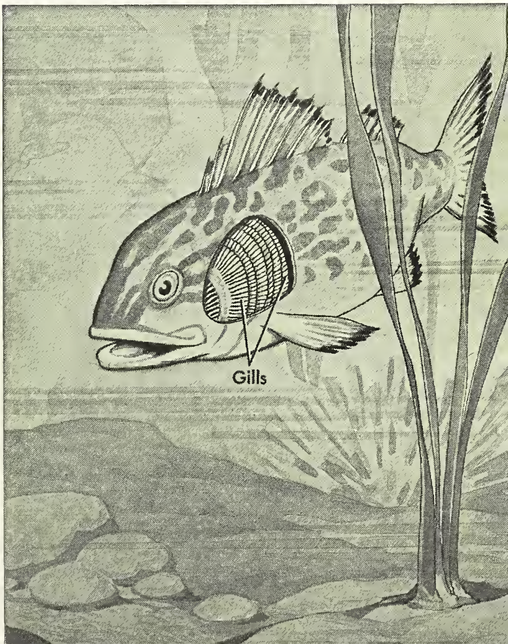
Sheep are born with long tails which are cut shorter, or *docked,* when the lambs are very young, in order to help keep their bodies clean.

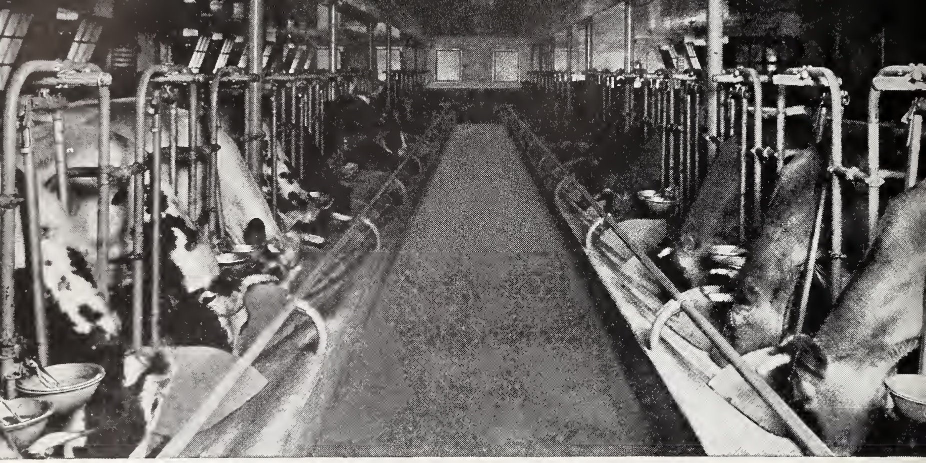
If cattle with horns are kept in herds, they may injure each other. They may also become difficult to handle. In order to avoid these difficulties, the horns of cattle are often removed.

SUMMARY

Shelters are provided for some animals to protect them from extreme temperatures, wind, and rain. When fish are grown in aquaria, they must be supplied with proper food and an adequate amount of water with sufficient oxygen dissolved in it. The appearance and comfort of some animals may be

Water is gulped by the fish and forced over the gills (shown with covering removed), where oxygen from the water enters the fish's blood and carbon dioxide is given off into the water.





National Dairy Council

The kind of shelter provided for livestock is important. A clean, up-to-date barn, where the temperature is kept even and ventilation is good, will make it possible to get more milk from cows, than a less protected shelter.

improved by cleaning their coats, caring for their feet, docking their tails, or removing their horns.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words on your answer sheet which should be substituted for the italicized ones to make the statement true.

1. *Horses* should be protected from drafts.
2. In order to increase egg production, hens should be kept in *dark* henhouses, where even temperatures can be maintained.
3. Fish use their *lungs* to obtain oxygen dissolved in water.
4. It is desirable to have green plants growing in the water in which fish live because they remove *carbon dioxide* from the water.

CHAPTER ACTIVITIES

REVIEW ANIMAL CARE

Four major needs of animals are listed below, followed by a list of man's activities in caring for animals. In the proper place on your answer sheet, beside the letter of each activity, write the number of the major need to which it contributes. **Do not write in your textbook.**

MAJOR NEEDS OF ANIMALS

1. A balanced ration
2. Protection from natural enemies
3. Protection from weather
4. Protection from physical injury

MAN'S ACTIVITIES IN CARING FOR ANIMALS

a. Building warm, well-ventilated doghouses
b. Spraying cattle with DDT
c. Nailing metal shoes on horses' hoofs
d. Keeping a good supply of grass on the ranges where there may be poisonous plants
e. Erecting livestock sheds
f. Trimming canaries' claws
g. Bathing dogs
h. Keeping canaries in cages closed on one side
i. Inoculating animals
j. Feeding oyster shells and bone meal to hens
k. Mixing tankage with animal food
l. Including vegetables in a cat's ration
m. Making silage

SELECT HYPOTHESES

Several days after a heavy rain had washed a large quantity of soil, plants, and other organic matter into a small lake, many dead fish were found floating on the surface of the water. The lake had previously been a popular fishing place for many of the people living in the surrounding area, and they were anxious to determine what had caused the fish to die. Several hypotheses suggested by different persons are listed below. On your answer sheet, write the number of the hypothesis which you think is most reasonable.

1. So much rain water had run into the lake that it drowned many of the fish.
2. When the organic matter washed into the lake began to decay, so much carbon dioxide was given off that it poisoned the fish.
3. During the heavy downpour of rain, the oxygen supply from the air was cut off; therefore there was not enough oxygen to supply all fish.
4. The thunder of the storm produced sound waves in the water that killed the older fish.

Bureau of Plant Industry, Soils, and Agricultural Engineering

Plant breeders cross-pollinating selected brome grass. Pollen from the flower of one selected plant is being emptied into the sack-covered flower of the other. Sacks are used to prevent pollination from other plants.

chapter 22 IMPROVING LIVING THINGS

MAN is concerned with improving both the quality and quantity of living things. He wants wheat plants that rust, smut, and other diseases will not damage. He wants corn plants that will grow well in dry climates. He wants peach trees that will produce large, firm peaches with a color appealing to buyers. He wants plants that will produce large, colorful flowers to decorate his garden and his home. He wants animals that are best suited for the various environmental conditions under which they must live in different sections of the country. He wants dairy cattle that will produce more and better milk. He wants hens that will lay eggs every day. In order to meet these and the many other wants of man for better plants and animals, scientists known as plant and animal *breeders* are constantly attempting to improve living things.

PROBLEM 1. How are plants improved?

ORIGIN OF CHARACTERS

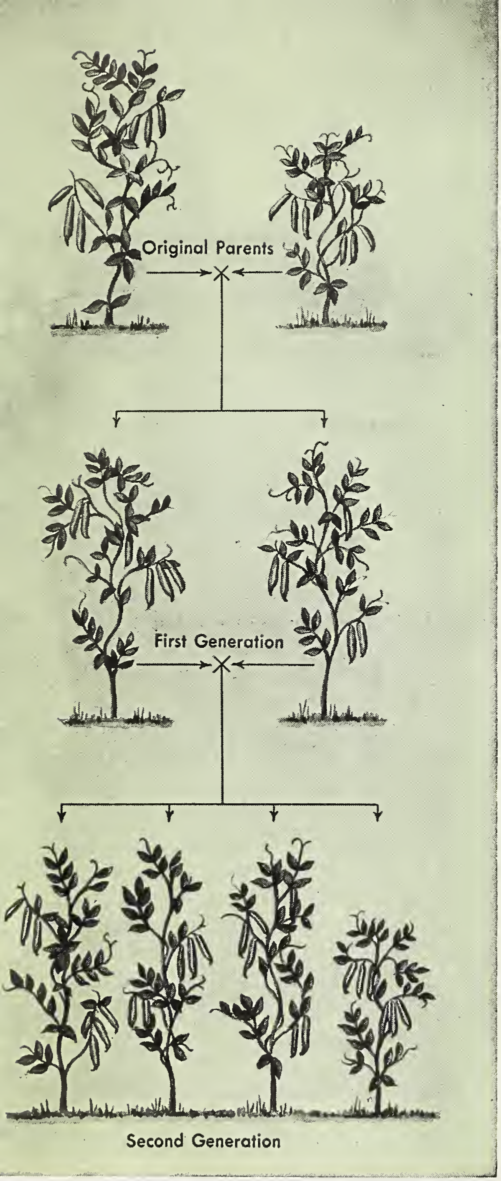
Characters obtained from parents. The kind of plant that will develop from a particular seed; the size to which it can grow under favorable conditions; the color of its flowers; the kind of fruit it will produce; and all such characters are passed on or *inherited* from its parents. The process whereby characters such as those named are inherited from parents is called *heredity*. As a result of heredity, plants will produce only their kind of plant. A parent wheat plant may produce as offspring other wheat plants very much like it. The offspring may be the same size, produce the same amount of seed, and have many other characters that are similar to the parent. These similar characters are transmitted from parent to offspring by heredity. But another parent wheat plant may produce offspring that are not like it in all characters. The offspring may be shorter or taller, produce more or less seed, and differ in other ways from their parent. These differences are also inherited. It is important to remember that not only the similarities but also the differences between plants of any one kind are determined by heredity. A wheat plant which differs from other wheat plants in one or more characters, such as heights, is called a *variety* of wheat.

Mendel's experiments. The way the various characters of plants are inherited has not always been understood. About one hundred years ago, an Austrian scientist named Mendel conducted experiments with garden peas. His experiments proved a number of things about the way characters are inherited.

In one of his experiments, Mendel worked with tall and short pea plants. He self-pollinated the tall pea plants for a number of years and found that they always produced tall offspring. He concluded from this that these pea plants could produce only tall offspring. Such plants are called *pure line* for the character of tallness. Similarly he selected a pure line of short pea plants.

Mendel then *crossed* the pure-line tall plants with the pure-line short plants and discovered that all offspring resulting from this cross were tall. Whenever pollen from the flower of one plant is used to pollinate the flower of another plant so that fertilization results, the plants are said to be *crossed*. Offspring produced by crossing two pure-line parents which are unlike with regard to a particular character are called *hybrids*. Since all of Mendel's hybrid peas were tall, he considered the character of tallness to be more effective, or *dominant* over the character for shortness. Since the character for shortness was less effective, Mendel called it *recessive*. He then self-pollinated a large number of these tall hybrid pea plants and carefully examined all the offspring they produced. He found that approximately 25 per cent of the offspring produced by the self-pollinated hybrids were short whereas 75 per cent were tall.

Continuing to experiment, Mendel obtained similar results when other characters of pea plants, such as the color of seeds, were studied. He found that the character for yellow-colored seeds was dominant over the character for green-colored seeds. These experiments proved that it was possible to



Mendel found that when tall pea plants were crossed with short pea plants the first generation offspring were all tall. When these offspring were crossed, one fourth of the second generation pea plants were short and three fourths were tall.

regulate the reproduction of plants so that specific characters could be obtained. This practice is called *controlled breeding.*

Determiners of characters. Scientists have continued with experiments similar to Mendel's and have made other important discoveries regarding the way heredity operates in living things. Scientists today believe that the determiners of inherited characters are present in the nucleus of all cells. They further believe that these determiners are transmitted through the reproductive cells from parents to offspring. The determiners of characters which a plant will inherit from its parents are, therefore, carried in the sperm and egg nuclei. When the sex cells unite at fertilization, both parents contribute an equal number of determiners to their offspring.

Characters not obtained from parents. Sometimes a plant or animal will appear possessing a character which neither its parents nor its grandparents possessed. Nevertheless, when this plant or animal reproduces, it passes that character on to its offspring. Whenever such a character not inherited from parents appears, it is called a *mutation.* Mutations are not uncommon among living things. Living things in which mutations appear are called *mutants.* Some mutants, such as the seedless orange, are valuable to man. Other mutations may be undesirable.

IMPROVING PLANT CHARACTERS

Determining desirable characters. Before any attempts can be made to improve plants by controlled breeding, it is necessary to determine which characters of plants are most desirable. It is

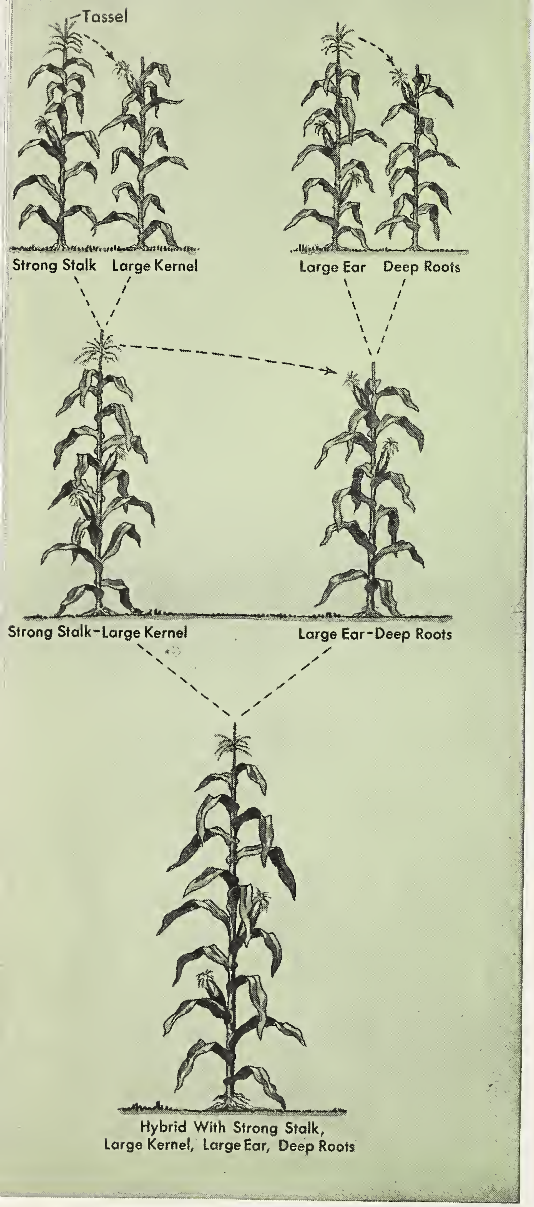
Bureau of Plant Industry, Soils, and Agricultural Engineering

Mr. William S. Porte, a government scientist, is holding three Pan American tomatoes which he developed by selection and crossbreeding. Before him are the parents. The small currant tomato, discovered in Peru, was resistant to wilt. The large Marglove tomato was a good producer but had low resistance to wilt. Their offspring, the Pan American, possesses desirable characters from both parents.

generally agreed that high yield in crop plants is desirable. But what inherited characters have a close relationship to the ability of the plant to produce high yields? Resistance to disease and insects, ability to withstand drought, size of the fruit produced, and hardiness of the plant are related to high crop yields.

Selecting disease-resistant plants. Crop losses each year from plant diseases are very great. One of the best ways to prevent such losses is to develop a plant that has the inherited characters which make it naturally resistant to disease. For example, scientists are working on experiments to select disease-resistant tomato plants.

Crossbreeding to obtain disease-resistant plants. Disease-resistant plants are also obtained by a process known as *crossbreeding*. Many thousands of crosses may be made before the desired offspring is obtained. A number of disease-resistant varieties of wheat have been developed by crossbreeding. Many of them are resistant to rust, smut, and other diseases. It has been estimated that new varieties of wheat have increased wheat production by millions of bushels.


Tassel
Strong Stalk
Large Kernel
Large Ear
Deep Roots
Strong Stalk-Large Kernel
Large Ear-Deep Roots
Hybrid With Strong Stalk,
Large Kernel, Large Ear, Deep Roots

The desirable characters of four corn plants are brought together by crossbreeding in two corn plants, and finally in one hybrid corn plant. Tassels are removed from one parent in each cross to prevent self-pollination.

Insect-resistant plants. Plant breeders have also developed crop plants resistant to attacks by insects. Although their attempts in this field have not been as successful as in the development of disease-resistant plants, many insect-resistant plants have been discovered or developed. These plants are not resistant to all insects, but each has shown a rather high resistance to one or more. Some of the more outstanding examples are a variety of *sorghum* plant resistant to chinch bug, barley resistant to green bug, alfalfa resistant to pea aphid, a sugar beet resistant to beet leaf hopper, sugar cane resistant to sugar-cane borer, and corn resistant to the corn borer. Each plant possesses certain characters that make it unattractive to insects.

Hybrid corn. Corn is one of the most important crops produced in the United States. Plant breeders have worked for a long time in developing varieties that will produce larger and larger yields. One of the most important achievements of the corn breeder has been the development of hybrid corn. Remember that hybrids are produced by crossing two varieties unlike with respect to one or more characters. In hybrid corn, each parent must possess one or more desirable characters. Usually the parents themselves are not a generally good type of corn because of certain inferior characters they also possess. If, however, the most desirable characters of each parent can be brought together by being crossed, the hybrid may develop into a highly desirable corn plant. The way this is accomplished is shown at left.

Other plant hybrids. Plant breeders are experimenting with many other kinds of plants in an attempt to produce hybrids that will be as successful as hybrid corn. Some hybrids of alfalfa yield 25 per cent more hay than the ordinary alfalfa. Hybrid blueberries promise to increase blueberry production throughout the United States. Hybrid onions, tomatoes, squash, cucumbers, strawberries, and snapdragons are great improvements over the ordinary varieties of these plants.

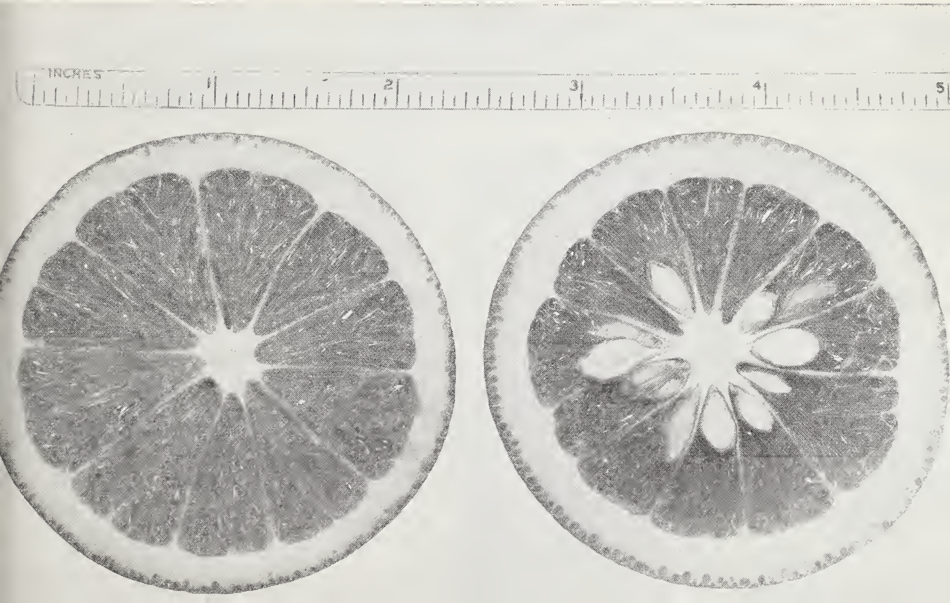
Plant breeders believe that there will soon be hybrid forest trees which will grow to harvesting size in one half the time required by other trees. They have already developed a hybrid pine tree that grows taller and heavier than either of its parents.

Improving nutritive value. The vitamin C contained in tomatoes makes them a desirable food. Some varieties of tomatoes contain three or four times as much vitamin C as other varieties, but these plants generally produce fruits that are too small to be of any value. By controlled breeding, plant breeders may develop a variety of tomato with large marketable fruit and with the maximum vitamin C content.

Natural selection. A natural process resulting in the development of new varieties has been taking place since the first plants appeared on the earth. Plants have always had to struggle with other plants and their environment in order to live. Occasionally a plant has appeared possessing a new character that made its chances of living better than the other plants to which it was related. When the improved plant reproduced, it transferred the new character to its offspring. Since more of these offspring would live and produce other offspring, they would

The seedless character of the orange on the left appeared first as a mutation. It proved desirable for man, since he generally propagates orange trees by grafting, and not by seeds. It would have been an undesirable character for the orange because without seed it could not reproduce itself.

University of California, College of Agriculture



eventually replace all plants that did not possess the new character. This process, called *natural selection,* has operated toward the development of new varieties of plants. Whenever plants appeared possessing new characters that made it less possible for them to live, they soon died.

SUMMARY

The characters of a plant which determine the kind of plant it can become under the best environmental conditions are inherited from its parents. In order, therefore, to improve the quality and increase the quantity of plants, man has selected the parents of plants and controlled their reproduction. By controlled breeding, plants are being developed which produce high yields and more nutritious food products, and are resistant to drought, insect attacks, and diseases.

DEMONSTRATION

Generalization to be demonstrated. The offspring of self-pollinated hybrids show an approximate 3-to-1 ratio of dominant over recessive characters.

What you need. Several large flowerpots; soil to fill the pots; self-pollinated seed of sorghum or kaffir corn with green dominant and *albinism recessive*. Albino plants have no green coloring. Albino sorghum seed can be obtained from the Brooklyn Botanic Garden, 1000 Washington Avenue, Brooklyn 25, New York. Albino kaffir corn can be obtained from Texas Agricultural Experiment Station, Lubbock, Texas.

What to do. Fill the flowerpots with soil to within 1 inch of the top. Plant 100 seeds of either maize or kaffir corn and allow them to grow into seedlings. (*Note:* If more than 100 seeds can be planted, the chances of getting results closely approximating the 3-to-1 ratio are higher.) After the seedlings have developed, count and record the number of green and albino seedlings.

What to observe. What is the ratio of green to albino seedlings? (Obtain the ratio by dividing the number of green seedlings by the number of albino seedlings.)

What does it mean? 1. How does the ratio obtained tend to prove or disprove the generalization as stated at the beginning of the demonstration?

2. How do you account for a ratio which you may have obtained that is not exactly 3 to 1?

Basic assumptions in this demonstration. The difference in the color of the seedlings was caused only by hereditary characters. The seed used was obtained from hybrid plants.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Plants which always produce offspring with one character like that of the parents are known as (a) pure line; (b) recessive; (c) hybrid; (d) dominant.
2. A plant which possesses an entirely new character which can be passed on to its offspring is known as (a) a hybrid; (b) pure line; (c) a mutant; (d) a dominant character.
3. A variety of disease-resistant plants can sometimes be developed by (a) treating the seeds with chemicals; (b) treating the soil with chemicals; (c) selecting and breeding disease-free plants; (d) planting the seeds always at a certain time of the year.
4. If two varieties of plants that are unlike with respect to one or more characters are crossed, the offspring are known as (a) pure lines; (b) mutations; (c) recessive; (d) hybrids.

PROBLEM 2. How are animals improved?

DESIRABLE CHARACTERS

Production limited by heredity. The quantity and kind of meat, milk, wool, eggs, or work that any animal can produce is limited by the animal's inheritance. Production may be increased by supplying animals with better food and shelter, but the limit of production is controlled by the inherited characters of the animal.

The manner in which characters are transmitted from parent to offspring is the same in animals as it is in plants. It takes a longer time, however, to improve livestock by controlled breeding than it does to improve plants. A gen-

These White Leghorn chickens have been developed for high egg production. Many poultry breeders have developed flocks in which each hen lays from 200 to 250 eggs a year.

U.S. Department of Agriculture

eration of plants can be obtained in one year, but it takes several years to obtain a generation of some types of livestock.

Desirable characters. Before animals can be improved through controlled breeding, the breeder must know what characters are most desirable in the animal he wishes to improve. Many studies have been conducted to determine the most desirable characters of animals. If the animal is to be developed for meat, one set of characters is important; if for milk production, another set. Hens, sheep, cattle, hogs, race horses, and even pets have been bred by man for special purposes.

Selection, inbreeding, and crossbreeding. *Selection, inbreeding,* and *crossbreeding* are three basic ways in which livestock are improved. The person who raises animals, having decided upon the characters he wishes to develop, selects only those animals possessing the desired characters to a high degree. Various methods of judging and scoring animals are used in making the selection. The selected animals are then used to produce offspring. Out of all offspring, only those are selected definitely possessing the desired characters. These animals are then used as parents and again only the best selected from their offspring. This is called inbreeding and may be continued indefinitely.

Most purebred livestock have been developed by inbreeding. After purebred animals are developed by inbreeding, the breeder may crossbreed two purebred animals possessing desirable characters, in an attempt to bring the desirable characters from both lines together in hybrid offspring.

The hog on the left was developed as a bacon producer whereas the one on the right is a lard producer. Although they are both hogs, they differ in a number of ways.

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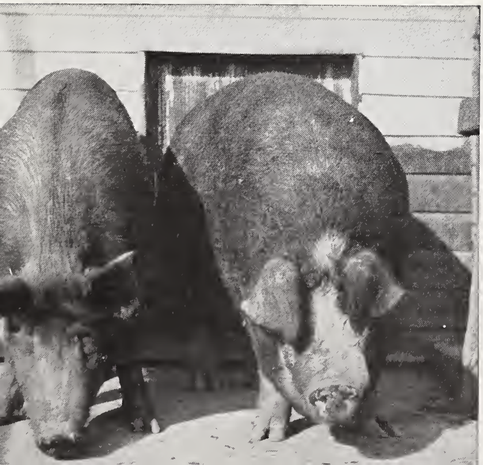
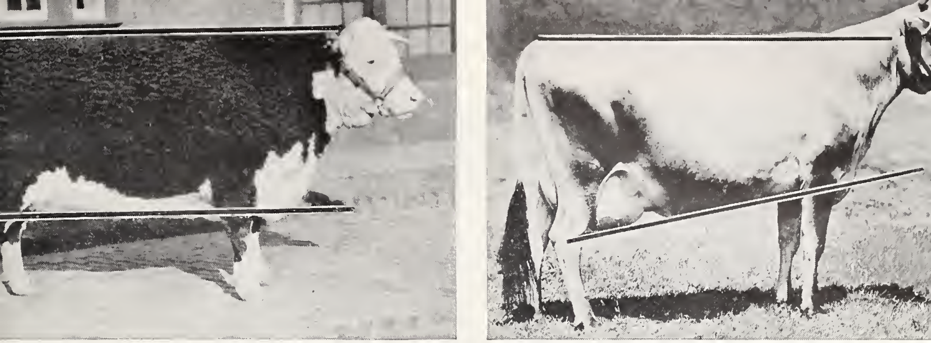


WHY CHANGES ARE MADE

Improvement of animals. Most of the changes we have made in animals have been to improve or increase the food supply. Having found that one kind of hog gives more lard, another better bacon, the farmer by controlled inbreeding was able to raise more of the kind most profitable to him. See picture at left for characters of each.

Some sheep give better meat, others better wool. Careful selection and breeding have made it possible for the sheep raiser to produce the type sheep most profitable to him. Cattle too are developed for either milk production or beef production, although some dual-purpose types may be developed for both.

Chickens can be developed to lay more eggs or to produce better meat. Those shown on page 421 were especially raised to give more eggs with better shells and improved quality of egg material.



U.S. Department of Agriculture

The animal at left has the rectangular shape typical of the beef-producer, that at right the wedge shape typical of the milk-producer.

By keeping careful records, it has been possible to determine the characters making for greater speed in race horses. By controlled breeding horses have been produced which have a better chance of becoming champions.

Because man uses domesticated dogs not only for pets but also for some kinds of work and for hunting, he has developed certain characters most desirable for his special purpose. Pointers and retrievers are good hunters. Alaskan malemutes and collies do some kinds of work, and Boston terriers and poodles merely please man by their appearance.

Animal - improvement associations. Many different local and national associations have been formed to promote the improvement of animals. Members of an association of local cattlemen or dairymen may each contribute a part of the money needed to buy one or more purebred bulls to use in improving the inherited characters of young calves produced by their cows. A cattleman interested in raising only purebred cattle may join a national breeders' association, which keeps a complete hereditary record of purebred animals registered with it. These records are made available to persons interested in buying purebred livestock. There are associations for registering almost every type of animal that man raises. These associations help maintain high standards of inherited characters among livestock and pets.

SUMMARY

We improve animals by selecting those individuals that possess desirable characters and by controlling their breeding so that the desirable characters are transmitted to their offspring. Only through careful study can we determine the characters that produce the kind of animal we want.

TEST YOURSELF

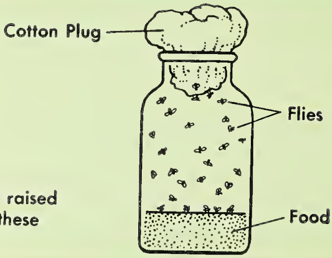
In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Some livestock are improved more slowly by controlled breeding than are plants because (a) less is known about the heredity of livestock; (b) heredity in livestock has not been

studied; (c) the laws of heredity which apply to plants do not apply to livestock; (d) it takes several years to obtain a generation of some types of livestock.

2. Hogs have been improved by the development of types that (a) look like the ancestor of all hogs; (b) can run fast; (c) produce more meat of better quality; (d) eat very little food.
3. Dual-purpose cattle have been developed by (a) giving them good rations; (b) inbreeding; (c) training them properly; (d) crossbreeding.
4. National associations of cattlemen have been formed to (a) sell cattle; (b) distribute eggs; (c) improve inherited characters of livestock; (d) improve the soil where cattle are put out to pasture.

OBSERVATION



Fruit flies can be raised in bottles like these

What to observe. Inheritance of white-eye and red-eye in fruit flies.

How to observe it. This activity will require a good deal of time, patience, and co-operation. But the results will be well worth the effort. Since this project will take time to complete, a committee from the class might undertake it, and report back to the class when the work is done.

Drosophila, or fruit flies as they are commonly called, have been widely used in hereditary experiments. Eye color is one characteristic that has been studied. These flies are often found around fruit, and they can be easily raised in bottles as shown. Turtox Leaflet No. 15, published by General Biological Supply House, 761-763 East 69th Place, Chicago 37, Illinois, contains detailed instructions on obtaining flies, preparing the food media, mating them, and observing their offspring. After you have obtained and studied the leaflet, you should be able to cross a pure-line white-eyed fly with a pure-line red-eyed fly and observe their hybrid offspring. You might then want to mate the hybrids to see what kind of offspring they produce.

Interpretation of your observation. What color eyes do the hybrid offspring have? How can you explain this?

CHAPTER ACTIVITIES

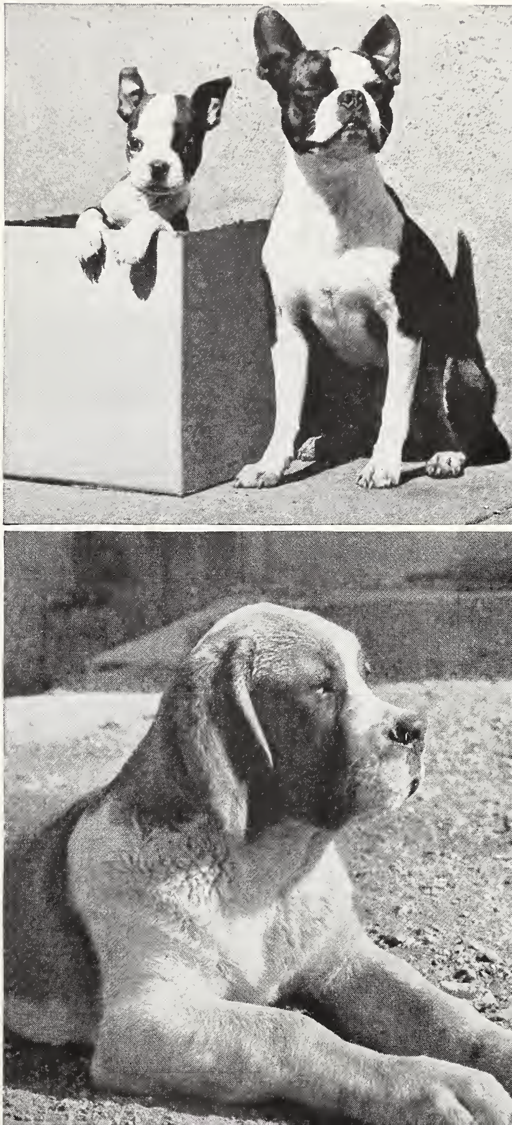
FORM A GENERALIZATION

Two important generalizations developed in this chapter are listed below. Following each is a list of statements some of which were used in forming the generalization. On your answer sheet, write the letters of those statements used in forming the generalization under which they are listed.

1. The characters of a plant or animal which determine the kind of plant or animal it can become under good environmental conditions are usually inherited from its parents.
   a. Pure-line tall pea plants always produce tall pea plants.
   b. Plants that grow in good soil are likely to be more healthy than plants that grow in poor soil.
   c. Seedless oranges are raised by vegetative propagation.
   d. The Pan American tomato is wilt-resistant and large.
   e. Hogs grow faster on less food when given antibiotics.
   f. High prices are paid for young colts from parents having good racing records.
2. Through selection and controlled breeding, man can develop plants and animals that are most useful to him.
   a. Some hens will produce as many as 300 eggs per year.
   b. Fertilizers are used to increase crop production.
   c. New varieties of wheat increased the total wheat production in the United States by more than 800 million bushels between 1942 and 1946.

Each of these animals has inherited characters which cause him to be a special type of dog different from all other types of dogs. Each has characters making him a desirable pet.

Philip Gendreau



d. The Jersey cow is a different color than the Holstein.

e. The value of corn crops has increased millions of dollars since farmers began planting hybrid corn.

CHECK YOUR UNDERSTANDING

You have learned that selection of characters together with inbreeding and crossbreeding are the ways man improves plants and animals. A number of examples of improvements in plants and animals are listed below. If the improvement came about as a result of selection and inbreeding, write the letter **I** in the proper place on your answer sheet. If the improvement came about as a result of selection and crossbreeding, write the letter **C** in the proper place on your answer sheet. **Do not write in your textbook.**

1. Breeding disease-free plants selected from a field of diseased plants
2. Producing the Pan American tomato from the currant tomato and the Marglobe tomato
3. Using seed only from insect-resistant plants of one variety
4. Producing hybrid corn
5. Developing a lard-producing type of hog
6. Breeding cattle for high milk production
7. Developing cattle for high butterfat content
8. Developing cattle for high quality meat

UNIT ACTIVITIES

APPLY YOUR KNOWLEDGE

Three of the generalizations developed in this unit are listed below, followed by a number of man's activities with plants and animals. Select the generalization illustrated by each activity and write its number beside the letter of the activity in the proper place on your answer sheet.

GENERALIZATIONS

1. We care for plants and animals by controlling the conditions necessary for their growth.
2. Plants and animals which better suit our needs can be developed by controlling their inheritance.
3. We propagate plants and animals by aiding their natural methods of reproduction.
4. We aid the growth of plants and animals by protecting them from their enemies.

ACTIVITIES

a. Spraying plants with contact poison

b. Using greenhouses, hotbeds, and coldframes when germinating seeds

c. Grafting part of one plant on to another plant

d. Developing a sorghum plant resistant to chinch bugs

e. Spraying an animal with DDT

f. Collecting tulip bulbs and planting them in the fall

g. Growing mushrooms in caves

h. Hatching chickens in electric incubators

i. Keeping young birds in brooders
j. Dumping oyster shells back into the water from which the oysters were taken
k. Irrigating fields in dry regions
l. Spraying a lawn with 2,4-D
m. Spreading milt over fish eggs
n. Spreading fertilizer on the lawn
o. Forming animal improvement associations
p. Raising purebred livestock
q. Planting hybrid corn
r. Making media to grow bacteria

REPORT ON PLANTS AND ANIMALS

1. Mutants which have been useful to man
2. Propagation of game animals in your state
3. Unusual animals as pets
4. Feeding antibiotics
5. Irrigation in the United States
6. The oyster industry
7. Using the praying mantis in controlling insects
8. The story of the ladybird beetle
9. A balanced ration for my pet
10. How some variety of dog, cat, horse, cow, or other animal was developed and is being further improved.
11. The use of radiations in producing mutations
12. Hybrid pine trees

LEARN ABOUT LIVING THINGS

1. Graft some plants using some of the methods illustrated on page 368.

2. Place some yeast in a 5 per cent sugar solution, and allow it to stand in a warm place overnight. Examine some of the solution with a microscope. (*Note:* Use the high-power objective and reduce the light as much as possible.)

3. Obtain some water from a stagnant pool and examine it with a microscope.

4. Perform an experiment to show the effect of different antiseptics and germicides on the growth of bacteria. Use agar media cultures similar to those prepared in Chapter 18, experiment on page 339.

5. Plan an experiment to test the relative effectiveness of commercial fertilizers.

6. Demonstrate how growth-regulating chemicals hasten the development of roots on cuttings.

7. Demonstrate how weed-killers are used on lawns.

MAKE VISITS

1. A pet shop to see how the animals are cared for
2. A fish hatchery to see how fish are propagated
3. A nursery to see how plants are propagated
4. A pet hospital to see how injured and sick pets are cared for
5. An agricultural experiment station to see how experimental work with plants or animals is carried on
6. A poultry farm to see how hens are cared for

READ ABOUT LIVING THINGS

Ellis, Carelton, Swaney, M. W., and Eastwood, Tom. *Soilless Growth of Plants.* New York: Reinhold Publishing Corp., 1938.

After a brief but simple explanation of the chemistry of plant life, this book describes the solutions, containers, and types of materials in which plants can be grown without soil.

Fabre, Jean Henri. *Insect World.* New York: Dodd, Mead & Company, 1949.

A new edition of a classic, edited by Edwin Way Teale, written simply and interestingly. Fabre's insect world was in his own back yard. Beautifully illustrated.

Greenberg, Sylvia S., and Raskin, Edith L. *Home-Made Zoo.* New York: David McKay Co., Inc., 1952.

An excellent description of the habits of a number of small animals, such as the hamster, that might be kept as pets in the home. Detailed instructions are given on how to take care of them.

Kains, M. G., and McQuesten, L. M. *Propagation of Plants.* New York: Orange Judd Publishing Co., 1953.

A most reliable and complete source of information on how to propagate many different kinds of plants.

Lane, Ferdinand C. *All About the Insect World.* New York: Random House, Inc., 1954.

This book offers many strange facts about important and familiar insects.

Lorenz, Konrad Z. *King Solomon's Ring.* New York: Thomas Y. Crowell Co., 1952.

The human side of birds and animals delightfully described by a world famous naturalist.

Mason, C. Russell. *Picture Primer of Attracting Birds.* Boston: Houghton Mifflin Company, 1952.

Tells in detail how you can make birds a feature of your landscape.

Morgan, Alfred. *A Pet Book for Boys and Girls.* New York: Charles Scribner's Sons, 1949.

Includes practical information on how to house and care for many kinds of pets.

Neider, Charles, editor. *Fabulous Insects.* New York: Harper & Brothers, 1954.

Twenty-four fascinating stories of "fabulous" insects.

Pyenson, Louis. *Pest Control in the Home Garden.* New York: The Macmillan Company, 1944.

Answers are given in a simple and direct way to the many problems faced by amateur and experienced gardeners in their war against plant pests.

Sterling, Dorothy. *Insects and the Homes They Build.* New York: Doubleday & Company, Inc., 1954.

Here you visit the silk tents of caterpillars, the cocoons of silkworms, the webs of spiders, the bubble house of the potbellied froghopper, and the woodhouses of ants and beetles.

Walker, Ernest P. *The Monkey Book.* New York: The Macmillan Company, 1954.

Discussion of monkeys as pets and their care and housing. Pictures of various kinds of monkeys along with their habits and requirements are presented.

Westcott, Cynthia. *The Plant Doctor.* Philadelphia: J. B. Lippincott Co., 1949.

Covers the how, why, and when of plant disease and insect control in the garden.

Wyler, Rose, and Ames, Gerald. *Life on Earth.* New York: Henry Schuman, Inc., 1953.

Discussion of ways in which plants, animals, and men are alike, how life began, what it is, and how it is continued on land and sea.

Zim, Herbert S., and Gabrielson, Ira N. *Birds: A Guide to the Most Familiar American Birds.* New York: Simon and Schuster, Inc., 1949.

Studying birds is a fascinating hobby, and this book will help you learn the names of birds and where they live.

Zim, Herbert S., and Cottam, Clarence. *Insects.* New York: Simon and Schuster, 1951.

A pocket guide to familiar insects with 225 different ones in full color.

Soil Conservation Service

This is not only a beautiful scene; it is a farm on which the crops have been selected and planted in ways that insure greatest protection from loss of soil by erosion.

unit 10 CONSERVATION

PEOPLE from older countries who visit the United States for the first time are impressed with the beauty of many parts of our country, our large farms, the amount and variety of food we have to eat, the number of automobiles we drive, skyscrapers in such cities as New York, our free public schools, our libraries, and our hospitals. We too are proud of these things which make our country great. But how did they come to be? Will we always have them?

They have been made possible because of the abundance of natural resources with which this country was blessed in its early days: a deep fertile soil in which crops could be grown, large forests of trees to meet almost every need for wood and fuel; rolling grasslands where livestock could be fattened at little cost; a section of the earth that was rich in coal, oil, iron, and other valuable metals; and finally a people who were free and knew how to use these resources. These are the things that have made our country a great and wonderful place to live.

It is only proper that our natural resources should have been used for these purposes, but we have learned three things which should cause us great concern. First, in spite of the fact that we believed our supply of natural resources to be endless, it is limited. Second, unwise use of many of our resources has resulted in unnecessary waste. Third, we may be faced with shortages of important resources in the near future.

If our country is to continue to be a good place to live in, we must learn to use more wisely the natural resources that are left. This unit will help you understand some of the ways in which this can be done.

Soil Conservation Service

A soil conservation specialist helps a farmer to understand the value of soil and water conservation on his farm. They are using a conservation survey map of the region.

chapter 23 CONSERVATION OF SOIL, WATER, AND MINERAL RESOURCES

WE use the surface of the earth for many purposes. We build our homes on it and grow plants in the soil. We use water that is stored in the earth. Coal, oil, and metals are used to build machines and supply the energy to run them. Without these natural resources life would be difficult if not impossible.

In the early days there seemed to be no limit to our supply of these resources from the earth. For this reason many of them were not used wisely. But there is a limit, and today we are faced with possible shortages in some. The shortages will become extremely serious unless steps are taken to use our remaining resources more wisely.

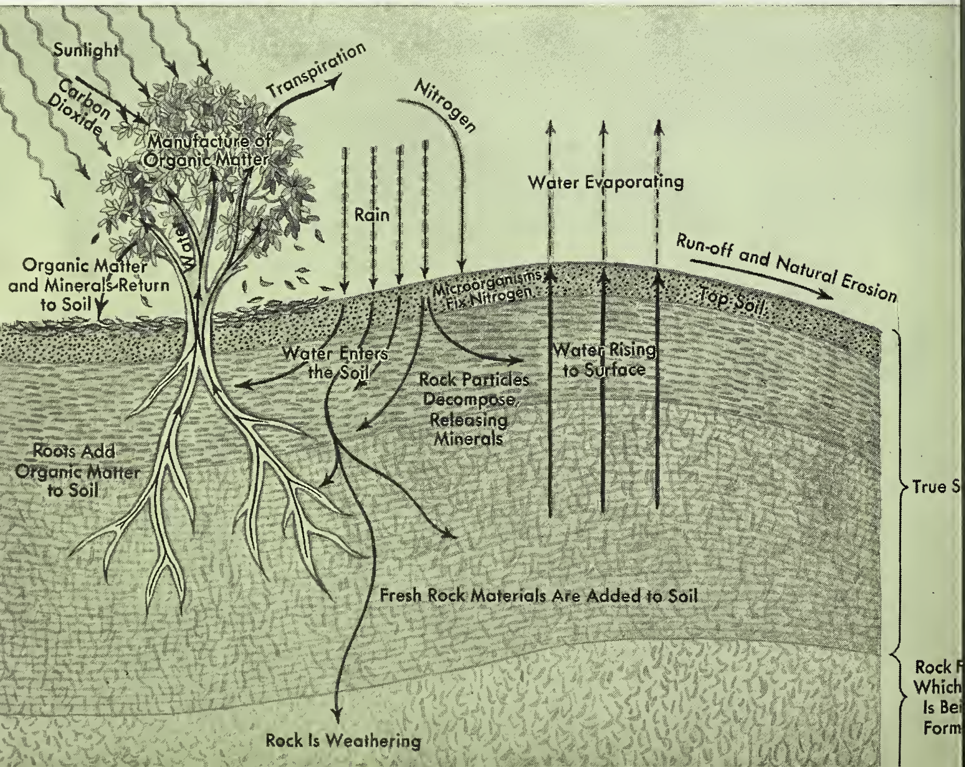
PROBLEM 1. How are we losing soil and water?

RELATION OF SOIL AND WATER

In order for green plants to grow in sufficient numbers to meet our needs, they must obtain water and minerals. They obtain these from the soil. Other living things besides plants depend upon water from rain and snow which collects in the soil and is stored in the surface of the earth. Soil and water supply are closely related. Whatever happens to the soil will have an effect upon our water supply.

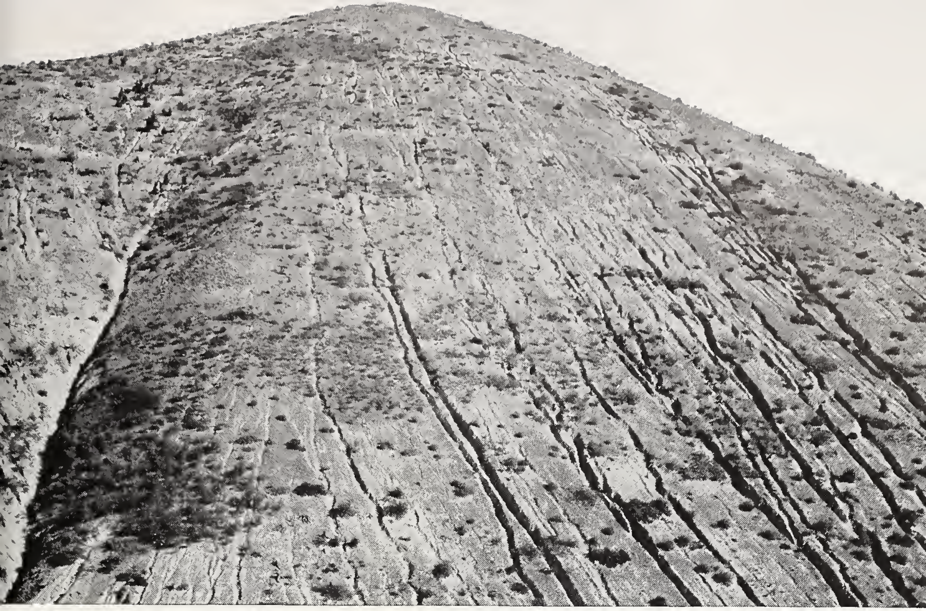
Formation of soil. Most soils are built up by plants from the rocky materials on the surface of the earth. The first plants to appear are dry, flat, crust-like structures called *lichens* which form greenish patches on the rock. As parts of the lichens die, bacteria cause them to decay, giving off carbon dioxide gas. When it rains, the carbon dioxide dissolves in the small amount of water that collects around the lichens, forming a chemical compound called *carbonic acid* (H_2CO_3).

Carbonic acid slowly dissolves inorganic materials out of the rock, causing the rock to crumble. This weathering of rock by lichens is very slow, but


Sunlight
Carbon Dioxide
Transpiration
Nitrogen
Manufacture of Organic Matter
Water
Rain
Water Evaporating
Run-off and Natural Erosion
Organic Matter and Minerals Return to Soil
Microorganisms Fix Nitrogen
Top Soil
Water Enters the Soil
Rock Particles Decompose, Releasing Minerals
Water Rising to Surface
Roots Add Organic Matter to Soil
True S
Fresh Rock Materials Are Added to Soil
Rock F
Which
Is Bei
Form
Rock Is Weathering

Some of the many processes that form soil are shown in this drawing. Although soil is formed from rock, both green plants and microorganisms play an important part in the processes whereby good rich topsoil is constantly but slowly being built up.

Adapted from "The Soils That Support Us," The Macmillan Company, 1941



U.S. Forest Service

This mountain was once heavily wooded but fumes from nearby smelters killed most of the trees. Without trees to hold it back, water from rain or snow runs down the hill washing away soil and forming gullies.

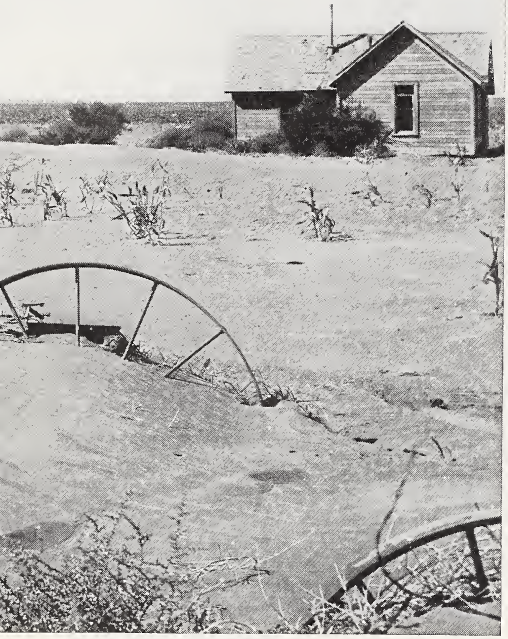
in time small depressions are formed in which rain water and the remains of lichens collect.

Other types of plants, such as moss, may begin to grow here. As the moss grows, weathering of the rock continues, and the depressions little by little become deeper. The decaying remains of moss plants also become mixed with the rock particles. It is the mixing of rock particles with organic matter from many sources that gradually forms soil.

As the soil becomes deeper, other types of living things grow in it. Gradually more bacteria, worms, insects, and other small animals find this newly formed soil a suitable home. Roots from larger plants spread throughout the soil, some of them growing into cracks in rocks and forcing the rocks farther apart. Worms and insects burrowing through the soil help mix the organic material with the rock particles. Bacteria continue to decompose dead plants and animals. As all this activity continues, more rock is weathered and mixed with organic material to form soil. The soil-forming process slowly penetrates deeper and deeper into the earth.

As you will remember, running water and glaciers break larger rocks into smaller pieces. When water penetrates into cracks in rocks and freezes, the expansion of ice may break the rock. The wind too may wear away fine particles from solid rock. All these forces aid in the formation of soil.

Topsoil and subsoil. The soil of the earth is divided into two layers, *topsoil* and *subsoil*. The topsoil at the surface is the older soil. Scientists who study soils estimate that it takes on the aver-



Soil Conservation Service

Improper use of the grasslands resulted in many scenes like the one shown here. The wind blew away precious topsoil and deposited some of it around buildings where it covered the farm machines.

age about a thousand years to form one inch of good topsoil. In some places the topsoil is only a few inches deep; in other places it is several feet deep. The soil underneath the topsoil is called subsoil. Topsoil is more fertile than subsoil because it contains more of the materials plants need for growth. The value of land for farming is determined largely by the depth of its topsoil. Though subsoil is younger and less fertile than topsoil, it supplies many of the materials needed by plants whose roots grow deep.

Topsoil may be transported several hundred miles from the place where it was formed. Winds blowing over dry, unprotected land pick it up and carry it away. It is washed into rivers by rain water. When the rivers overflow and flood the land, they deposit this soil. Such soil is generally very rich because it is the topsoil from land farther up the river.

Plants hold soil and water. When the first settlers came to America, vegetation covered the land wherever soil had been formed. There were large forests in sections of the country where climatic conditions were favorable to the growth of trees. In the prairie lands of limited rainfall, grasses grew abundantly. Although buffalo, deer, antelope, and other wildlife were plentiful, they did not remove great amounts of vegetation.

The vegetation prevented the rapid run-off of rain water so that most of it could be absorbed by the soil, saving both the water and the soil. Whenever the rains or melting snows were so heavy that plants could not keep the water from running off, the excess water carried some topsoil off with it. This is called *natural erosion* and has been going on since the earth was formed. However, where there was a dense mat of plant roots, soil particles were prevented from being washed away. Under the natural cover of vegetation, soils were built up faster than they were worn away at the surface.

LOSS OF SOIL AND WATER

Wasteful practices. The early settlers along the eastern coast of the United States removed trees, shrubs, and other vegetation to clear places for their homes and farms. When vegetation was removed from the slopes of hills, rain water ran off so fast that little of it could be absorbed by the soil. As the water ran down the slope, it carried precious layers of fertile topsoil with it. This has been called *man-made erosion*. The crops planted on the slopes of hills usually did not provide the soil with adequate protection from erosion.

Unwise lumbering practices in many places also resulted in the removal of forests that once helped to store water and to protect soil from erosion. As a result, not enough water seeped into springs to keep small streams flowing steadily down the hills throughout the summer. The rapidly melting snow in the spring ran off in torrents, and very little water was absorbed by the soil. Streams became dry during the summer, and less water seeped into underground storage places.

In the early days, the grasslands of the West supplied abundant feed for livestock. As more and more herds of cattle and sheep were raised, however, they destroyed the natural covering of grass. This left the bare soil exposed to wind and rain, with the result that rain ran off too rapidly to be absorbed by the soil, and the water carried good topsoil away with it.

Farmers followed the cattlemen. They plowed up large fields of the grasslands, planting more and more crops such as wheat in years when there was sufficient rainfall. When dry years came and wheat crops failed, the land was left practically barren of vegetation. The dry soil was picked up by the winds, and formed huge dust clouds that blackened the skies across the country. Much of this land, which became known as the "dust bowl," should never have been plowed because there was not enough water to raise crops year after year.

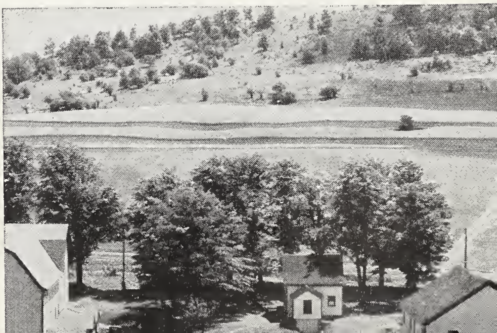
These wasteful practices, and others shown on pages 433 and 434, contributed to loss of water and soil erosion. Besides, since farm land was plentiful, few farmers made any attempt to keep up the fertility of the soil. The same crops, such as cotton or corn, planted on the same land year after year, used up important minerals from the soil. When the fertility of his soil became too low to make farming it profitable, the farmer moved farther west to new and better land. But today there is little new land.

The soil that is left. When water is lost, it eventually is returned to the land through the water cycle, but this is not so with soil. Once it has been washed away, it cannot be returned.

One third of the original farm land in the United States has been ruined or seriously damaged by erosion. One half of the area of the United States was land that originally could have been farmed. Approximately one sixth of the original farm land in the United States has been eroded so badly that it can no longer be used for practical farming. Another one sixth has been seriously damaged by erosion. Only about two thirds of the original farm land of the United States can today be considered good farm land.

A well-managed farm where the land is being properly used. Note that the steep slopes, instead of being cultivated, are being used to grow grass and trees.

Soil Conservation Service



SUMMARY

Soil serves man in two important ways: it supplies plants with minerals and water, and it aids in the storage of water. Plant life is not only necessary in building soils but also in protecting them from erosion. The removal of natural vegetation from the land without provision for adequate protection from erosion has resulted in a loss of about one third of the topsoil in the United States. The same conditions which cause loss of topsoil also cause loss of water.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words which should be substituted for the *italicized* ones to make the statement true.

1. It has been estimated that it takes over *1000* years to build one inch of topsoil.
2. Removing vegetation from a hillside allows *more* water to soak into the soil where it may be stored for future use.
3. *Natural* erosion was taking place in this country before the white man settled here.
4. In the early days, grasslands of the West supplied *less* food for livestock than the grasslands of today.
5. *One third* of the original farm land of the United States has been ruined or seriously damaged by erosion.

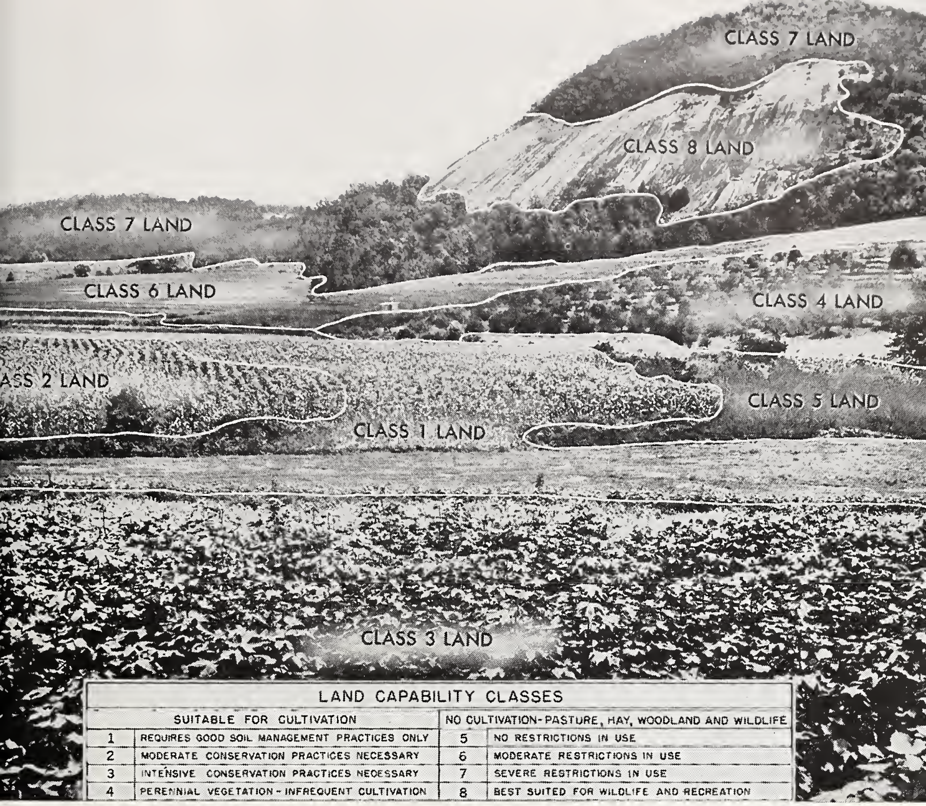
PROBLEM 2. How can we use soil and water more wisely?

USE OF THE SOIL

Our soil. Regardless of what we do for a living, we are all dependent upon the soil. If soil is wasted, there will be less food and other essential materials produced for our use. People who try to obtain a living by raising crops on worthless soil cannot produce enough to support themselves. Unless all of us become concerned about saving our soil, our standard of living may become much lower than that we now enjoy.

Working together to save the soil. Because farmers working individually have not been able to solve the important problem of soil erosion alone, the United States Department of Agriculture has developed a special service to help them. In 1934, through the cooperation of the United States Soil Conservation Service and farmers, soil-conservation demonstration areas were set up in different sections of the United States where erosion problems were most serious. Specialists in conservation and local farmers worked together to solve the problems involved in saving the soil.

Farm practices designed to protect the soil and increase its productivity were tried out. The successful practices were applied to farms throughout the demonstration areas. As a result, erosion was greatly reduced on some farms and completely controlled on others where the soil had been washing away at alarming rates. There were less frequent and less severe floods along streams in those areas, and the streams were not so muddy as they had been before. Wildlife became more abun-



LAND CAPABILITY CLASSES

SUITABLE FOR CULTIVATION		NO CULTIVATION-PASTURE, HAY, WOODLAND AND WILDLIFE	
1	REQUIRES GOOD SOIL MANAGEMENT PRACTICES ONLY	5	NO RESTRICTIONS IN USE
2	MODERATE CONSERVATION PRACTICES NECESSARY	6	MODERATE RESTRICTIONS IN USE
3	INTENSIVE CONSERVATION PRACTICES NECESSARY	7	SEVERE RESTRICTIONS IN USE
4	PERENNIAL VEGETATION - INFREQUENT CULTIVATION	8	BEST SUITED FOR WILDLIFE AND RECREATION

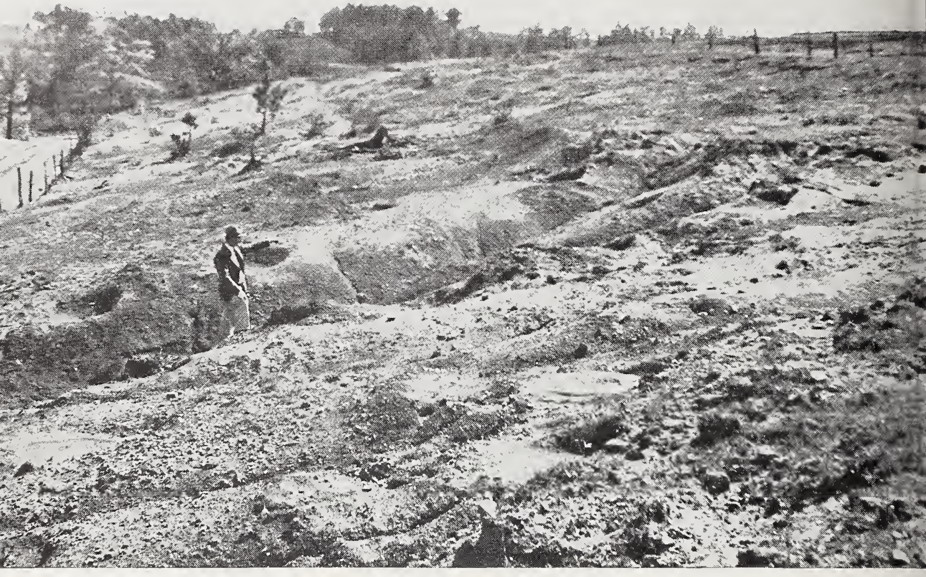
Soil Conservation Service

On a well-managed farm, land is classified and used according to the recommended practices for each class of land. Note how the various classes of land should be used.

dant in the demonstration areas. Many of the wet lands were drained and made suitable for agriculture, and there was a general increase in crop production.

The success of conservation practices became known to farmers outside the areas, and before long they began to request assistance in controlling erosion, conserving water, developing wildlife, draining wet lands, and controlling floods. Conservation laws have been passed which make it possible for farmers to organize soil-conservation districts in any state. Today most of the farms in the United States are in organized districts, although all of them are not as yet operating under active conservation plans.

Land classification based upon use. After a group of farmers has organized a conservation district, each co-operating farmer's land is carefully studied to determine how each part of it should be farmed. Soil scientists determine steepness of slopes and the directions in which the water will drain off the land. The soil is examined to deter-



Soil Conservation Service

Deep gullies resulting from improper use of land. The wrong kind of planting of the wrong crops caused destructive erosion.

mine the kinds of crops that can be raised most successfully on different parts of the farm. The land on the farm is then classified in terms of the way it should be used, as shown on page 437.

Once a farmer's land has been classified, he is expected to use it according to the recommended practices for the classes of land on his farm. It should be remembered that conservation districts are formed by the farmers themselves for the purpose of co-operating in conservation.

Ways of preventing erosion. *Contour farming* and *strip cropping,* as shown on page 429 have been used to control erosion on land that slopes. Contour farming is a method of plowing and planting crops on sloping land so that each furrow and row runs around the slope on the same level.

On the grasslands *contour furrows* are used to save the rain water. During heavy rains, much of the rain water will run off grassy slopes unless it is checked. Ditches or furrows are plowed on the contour of grassy slopes to hold the water that would otherwise run off. When water is held by furrows, more of it will soak into the soil where it will be available to grass plants during dry weather.

Control of gullies. Wherever there are unprotected rows, paths, or trails running down a slope, rain water may soon begin to wash the soil away. If the run-off of water in these little channels is not checked, the channels become deeper and deeper. Deep gullies form, shown in picture above, as the soil is worn away from the sides. The best way to control gullies is to keep them from getting started. Once they have formed, they can be controlled in the way shown on page 439.

Stubble mulching. The stalks of

Soil Conservation Service

The same gullies three years after they were planted. The heavy growth of plants shown here holds back rain water and decreases soil erosion.

crops such as wheat and corn remaining after the harvest are called *stubble*. Farmers used to burn it or plow it under soon after the crop was harvested. It has been demonstrated, however, that stubble will protect the soil if it is left on the land until time to plant the next crop. Now many farmers use an implement that loosens the soil but leaves the stubble. This practice, called *stubble mulching,* protects the soil from erosion, decreases evaporation, helps the soil to soak up more rainfall, and aids the growth of many useful bacteria in the soil.

Saving soil fertility. Plants use minerals from the soil. Most of these minerals are made available to plants as soil is formed from rock. The minerals contain calcium, nitrogen, phosphorus, potassium, and smaller amounts of a number of other elements essential for plant growth. When crop plants are removed, the elements they have obtained from the soil are taken with them. Since the mineral elements cannot be replaced from the rock particles in the soil fast enough to make them available for crop production, it is necessary to add fertilizers of various kinds to the soil. Methods for doing this were described in Chapter 20.

Some plants remove more of one kind of mineral element than of another. If the same crop were grown year after year on the same soil, the soil would soon give up all of the elements which that crop requires. To prevent this, farmers must also rotate their crops in order to keep up soil fertility. This practice, called *crop rotation,* means that a farmer, after growing one type of crop for a year, changes to another type the next year or two before going back again to the first crop. As you will recall, such plants as clover and alfalfa add nitrogen to the soil. For this reason, these plants are generally included in a rotation of crops.

USE OF WATER

Irrigation farming. In Unit 7 we learned that irrigation farming is one way in which man adjusts to dry climates. The Colorado-Big Thompson Project, shown below, is an example of the effort and money it takes to get water for irrigation.

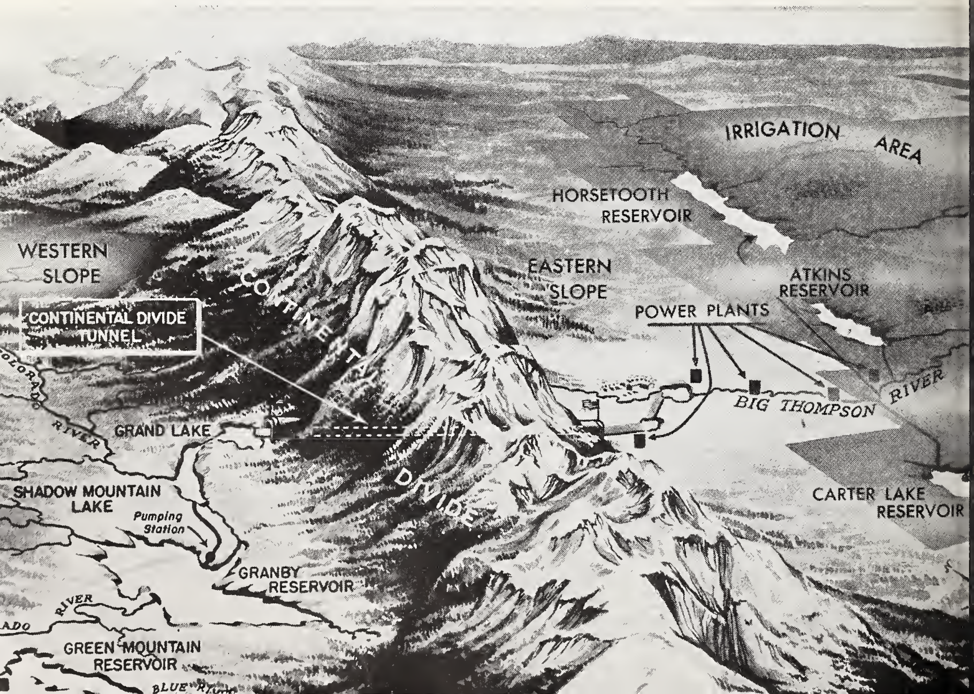
Since the amount of water for irrigated farms is limited, it should be conserved. Ditches that carry the water to the fields should be so constructed that water is not wasted by seepage into the ground. Such seepage, as well as erosion of soil along the ditch, can be eliminated if the ditch is lined with concrete, clay, or oil mixtures.

Water is also wasted when it is allowed to run through long rows in the field. It takes so long for the water to reach the end of a long row that more of it than is needed soaks into the soil at the beginning of the row, and much of it is lost. Whenever the irrigation rows are too steep, the water will not soak into the soil as well as it would in more level rows. Row crops should be planted in short rows on the contour.

Dry-land farming. Not all the rain that falls onto the land in dry climates can actually be used by plants. It has

The Colorado-Big Thompson Project in northern Colorado. Water from the Colorado River on the western slope of the Rocky Mountains is pumped into a tunnel that runs 13 miles through the mountains of the Continental Divide to the eastern slope, where the water is used to irrigate 615,000 acres of fertile farm land. Five hydroelectric power plants use the water as it flows down the Big Thompson River.

George T. Shahan



been estimated that about half the annual rainfall enters the soil; the other half evaporates or runs off into streams. Of the rain that enters the soil, less than one half is ever available to plants. The rest seeps too deep into the soil to be absorbed by plant roots.

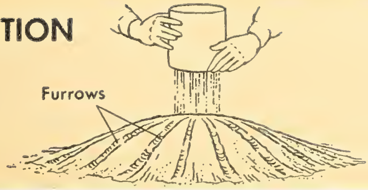
In dry-land farms where the annual rainfall is not sufficient to grow crops each year, and where irrigation water is not available, farmers must use different methods to save what little moisture is received by the soil. In some cases half of the dry-land farm is stubble-mulched and left idle each year to soak up and save enough moisture to grow a crop the second year. Two years of rainfall are, therefore, used to grow one crop. Saving moisture by letting land lie idle every other year is called *summer fallowing.*

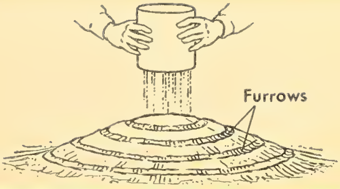
SUMMARY

There are two general types of land. One type is suitable for cultivation, although certain conservation practices may be necessary on some of it in order to prevent loss of soil and water. The other type of land should never be cultivated but should be used for other purposes. Whenever land is being used for the purposes for which it is best suited, the land is being properly managed.

Water can be saved and soil erosion can be controlled by proper management of land.

OBSERVATION



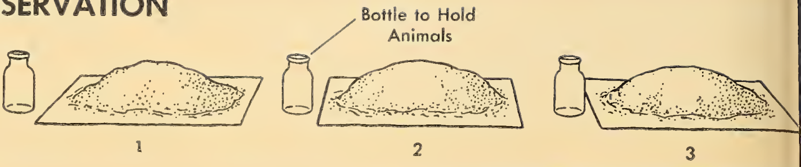


What to observe. The effect of contouring on soil erosion caused by water.

How to observe it. Build two mounds of topsoil about 12 inches in diameter and 3 or 4 inches high. With a pencil, match, or the finger, make furrows running up and down hill on one mound and around the hill on the other mound. Sprinkle the same amount of water on the top of each mound. Observe the amount of soil washed from each mound.

Interpretation of your observation. What evidence did you observe that contour furrows hold soil? What control should you have used in this observation? How would you plan another such activity to observe the effect of grass on soil erosion by water?

OBSERVATION

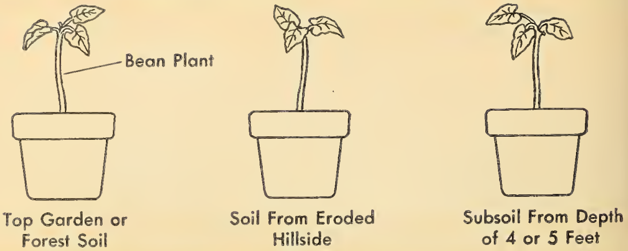


What to observe. Animal life in soils taken from three different places.

How to observe them. Obtain a shovel-full of soil from each of three places: (1) topsoil from a garden or woods; (2) soil from an eroded hillside; (3) subsoil from a depth of 4 or 5 feet. Spread each shovel-full out on a separate newspaper and count the number of animals that you can find by careful examination of the soil. It would be more scientific if you examined several samples of the same size from each of the three sources. Why?

Interpretation of your observation. In which soil did you find the largest number of animals? Explain why.

EXPERIMENT


Bean Plant
Top Garden or Forest Soil
Soil From Eroded Hillside
Subsoil From Depth of 4 or 5 Feet

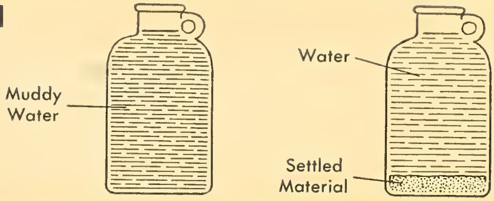
Questions to be answered. In which of three soils do plants grow best?

From your observation of the drawing, plan each of the following steps and perform the experiment:

1. **What you need.** List on another sheet of paper everything that you will need.
2. **What to do.** List on another sheet each thing that must be done in order to carry out the experiment. Make sure to plan how you will observe and record the results.
3. **Your answer.** Based upon the evidence you gather from this experiment, write in one sentence your answer to the question.

4. **Assumptions.** Keep these points in mind when looking for assumptions:
    a. Your controls
    b. Kind of plants used
    c. Way in which you measured the results
    d. Conditions under which the plants grew

DEMONSTRATION



Generalization to be demonstrated. Muddy water contains soil.

What you need. Several quart or half-gallon jars.

What to do. After a rain, when water is running off an area of unprotected soil, collect several jars of muddy water. Allow the bottles to stand for several days until the water becomes more clear. Pour off the water. Be careful not to remove any of the material that has settled out.

What to observe. Examine the mud on the bottoms of the jars. Allow it to dry and examine again.

What does it mean? 1. What evidence is there that this is soil?

2. How could you tell whether it was fertile soil?

3. Does this prove that all muddy water contains soil? What assumption would you have to make?

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. If a farmer has some land classified as Class II, he should (a) farm it with no concern about erosion; (b) not plant crops on it; (c) use special practices to prevent the slight erosion that might otherwise occur; (d) use it for pasture and not plow it more than once every six years.
2. The practice of plowing and planting around the slope of land instead of up and down the slope is called (a) strip cropping; (b) contour farming; (c) terracing; (d) stubble mulching.
3. The practice of leaving half the farm land idle each year is called

(a) stubble mulching; (b) strip cropping; (c) irrigating; (d) summer fallowing.

4. The farming practice known as crop rotation is carried on primarily to (a) save water; (b) prevent erosion by water; (c) keep the soil fertile; (d) prevent erosion by wind.

PROBLEM 3. How can we use our mineral resources more wisely?

MINERAL RESOURCES AS FUEL

Our mineral resources. Mineral resources are made up of those useful materials obtained from the earth. They include coal, petroleum, natural gas, iron, aluminum, magnesium, lead, zinc, copper, nickel, molybdenum, manganese, chromium, tungsten, and many others. As we learned in Unit 2, our mineral resources are fixed resources. Once they are removed, they cannot be replaced like water, forests, grasses, and wildlife. It is true that metal, such as iron and copper, may first be used to manufacture an article, and then used again to manufacture another article after the first is no longer usable. But once coal, petroleum, and natural gas are used as fuel, they are gone forever.

It is believed that forests such as these once covered areas of the United States where coal is now found. The coal was formed over the years from such plants as these.

Chicago Natural History Museum

The abundant supply of mineral resources available in the United States has been one of the important reasons for this country's becoming a great industrial nation. Large deposits of coal, oil, and natural gas have been available for use as fuel. Until 1946, coal furnished more than half of the energy used in the United States that came from mineral fuels and water power. In 1952, however, coal furnished only 34 per cent, petroleum 40 per cent, natural gas 22 per cent, and water 4 per cent.

Iron, the basic metal of industrial development, has been plentiful; in fact, more iron ore has been mined and used in the United States than in any other country in the world. This country has ranked first in the production of lead, zinc, and copper. With only about 6 per cent of the world's population, the United States uses 40 per cent of the world's output of mineral products in its many manufacturing processes.

Although our mineral resources in the United States are plentiful, we must be careful with them, for they are being used at an increasingly rapid rate. The amount of iron used per person has increased almost two and a half times since 1900, whereas the amount of petroleum used per person has increased about sixteen times. During wars mineral resources have been drawn upon heavily to produce military materials and equipment. It is estimated that during World War II we used up one fifth of our best copper reserves and one fourth of our best lead and zinc reserves.

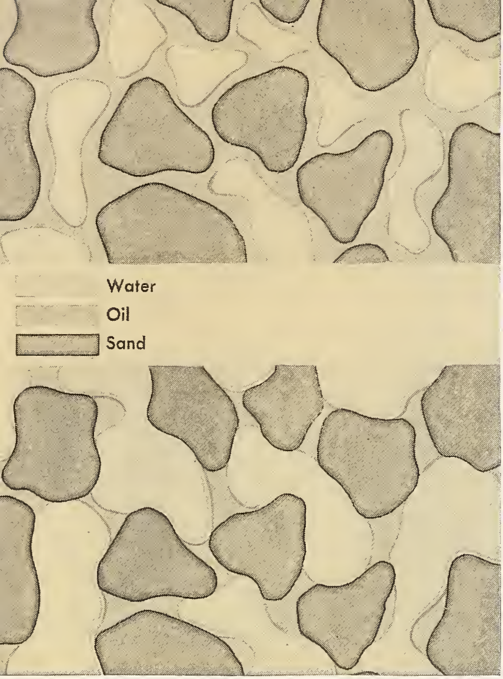
Coal. Studies of the available coal deposits in the United States show that we have sufficient coal to last us for many years to come, even if we continue to use it at our highest rate of almost 600 millions tons a year. We should be concerned about using it carefully, however, because coal is a fixed resource. Our supply cannot last forever. Some people argue that we should not be concerned because new sources of fuel will be discovered by scientists before we use up our present coal supply. Even if this is done, we should not waste our coal supply.

Coal is wasted in a number of ways: by improper mining methods; by inefficient coal-burning furnaces which produce heavy smoke containing large amounts of soot, made up of small particles of carbon; and by improperly controlled processes of making coke.

In order to reduce this waste, better mining methods must be used to remove coal more completely from the mines. Coal-burning furnaces should be constructed and operated to burn coal more efficiently. Poorer grades of coal should be cleaned so that they can be used more efficiently as fuels. Care should be taken in the manufacture of coke to heat the coal to obtain the greatest amount of coke from it and to save all of the useful by-products given off during the process.

Petroleum reserves. Petroleum, or oil, is being used in the United States at the rate of more than two and a half billion barrels a year. (A barrel of oil is equal to 42 gallons.) It is difficult to understand what it means to use oil at that rate until we compare the amount we are using each year with the amount of oil left in the earth. According to the best estimates by petroleum geologists, we had a proved crude oil reserve (as of December 31, 1953) of nearly 29 billion barrels in those sources that have already been discovered. Since each year new sources of oil are being discovered, our actual reserves of oil may be several times greater than the proved reserves. Although no one really knows, geologists believe that our oil reserves may last for about thirty or forty years at the rate at which we now are using oil.

Increased oil consumption. Within the next several years, oil will undoubtedly be used more and more as a source of power for transportation. Let us use automobiles as an example of what may happen. In 1947 there were approximately 30,000,000 automobiles in the United States. It has been estimated that by 1975 there will be about 65,000,000 automobiles, each using on the average about 650 gallons of gasoline a year. An increase of 35,000,000 automobiles will, therefore, result in an increased gasoline consumption of almost 23 billion gallons. The number of trucks, buses, tractors, and airplanes will also increase during this period which, in turn, will result in even greater demands for oil.



Microscopic views of sand particles surrounded by oil and water. Earlier methods of obtaining oil from wells left 70 to 90 per cent of the oil in the ground (top). Modern methods take about 80 per cent of the oil (bottom).

Oil is also used for heating homes, for supplying industrial power, and for manufacturing insecticides, perfumes, synthetic rubber, and many other products. As the demands for these products increase, more petroleum will be used.

Preventing the waste of petroleum. A great deal of petroleum has been wasted by improper methods of obtaining it from underground sources. Natural gas and water under pressure are dissolved in the oil within the places where it is stored in the earth. When a well is drilled, the gas often escapes through the opening in the well to the surface and forces some of the oil with it. In the early days of oil drilling, no attempt was made to control the gas escaping from an oil well; oil and gas often gushed from a newly drilled well with great force. The pressure of the gusher soon decreased and it became necessary to pump the oil out of the well. This expensive process removes only a small part of the oil; the remainder is left in the earth.

Geologists have learned that oil collects in sand and porous rock at great depths beneath the surface of the earth, and not in open pools, as it was believed at one time. The natural gas and water under pressure found in these oil-bearing sands and rock are necessary to move the oil and bring it to the surface. Knowing this, they were able to make most effective use of the natural gas and water pressure to obtain the greatest amount of oil from an underground source.

After the wells in an oil field have lost most of their driving force, two methods may be used to obtain additional oil. One method is to pump water into the oil-bearing sands through selected wells in the field. The water moves through the sands and forces the oil ahead of it to other wells from which it is removed. In the second method gas, that might otherwise be wasted, instead of water is forced into selected wells, producing the same effect as the water.

Other oil sources and substitutes. Even if we could obtain all of the oil now stored underground, eventually our supplies would be exhausted. Other sources will have to be developed.

The United States already is importing about 14 per cent of the petroleum it uses. Imports will increase until it costs less to distill oil from oil shale and to manufacture synthetic liquid fuels from natural gas and coal.

METALS

Iron. Iron is the basic metal for constructing the machines, tools, factories, railroads, and ships upon which an industrial nation such as ours depends. Fortunately we have had adequate supplies of iron ore in the past to meet our needs. The Mesabi Range in Minnesota has been producing one half the iron ore used in the United States.

However, the high-grade reserves are being used up rapidly, and we will have to import increasing amounts of high-grade ores from Canada, South America, and Africa, until the new developments, now under way, for extracting iron from the enormous low-grade ore deposits of Minnesota and the Great Lakes region are completed.

Other metals. In terms of the quantities we use, aluminum, copper, lead, magnesium, and zinc make up a group of metals next in importance to iron. No definite figures for total reserves of these and other metallic ores can be given as new deposits continue to be discovered. The reserves of magnesium are practically unlimited, since it is extracted from sea water. Another light metal, titanium, for which an extraction process has recently been developed, promises to be of great importance. It has the strength of stainless steel and weighs only half as much. The United States reserves of titanium are large but, as yet, it is costly to extract from its ores.

One prominent geologist has referred to manganese, chromium, nickel, molybdenum, and tungsten as the metal vitamins necessary to our nation's health. By this he meant that, although these metals are not used in such large quantities as some of the other metals,

Drake Memorial Museum

An oil field of 1865 contrasted with a modern one where there is one well for every 40 acres. It has been found that by properly spacing oil wells it is possible to increase greatly the sources. The older methods were extremely wasteful of our mineral resources.

Standard Oil Company

they are indispensable in manufacturing many essential products. The largest known deposits of molydenum in the world are found in Colorado. The best quality manganese and chromium come from Russia, and Canada supplies us with most of our nickel. However, if our supply from other countries were cut off, we could still obtain the metals from low-grade ore deposits in this country, but at much greater cost.

Because of its very wide use in the development of atomic energy, uranium has become an extremely important metal. Rich deposits of uranium ore outside the United States have also been used as a source of uranium.

Natural gas reserves. As of December 31, 1953, the proved reserves of recoverable natural gas were estimated at 211 trillion cubic feet. In 1953 over 8 trillion cubic feet of natural gas was sold to consumers. About one half of it was transported long distances (over 1,500 miles from Texas to New York) through pipe lines. In the last ten years, the volume of gas sold to consumers has increased two and one-half times.

How future shortages might be prevented. To prevent future shortages, it has been suggested that we should import larger quantities of these metals from other countries. This plan is in operation, and stockpiles of important metals needed quickly in times of emergency are well along toward the goals which have been set by the government. At the same time, the development of our low-grade ores and of more economical processes for extracting metals from them are being encouraged by the government. Scrap metal should be saved and profitable methods should be developed for reclaiming it, as well as for recovering by-product metal from all sources. Whenever possible substitute metals or other substitutes, such as plastics, should be found.

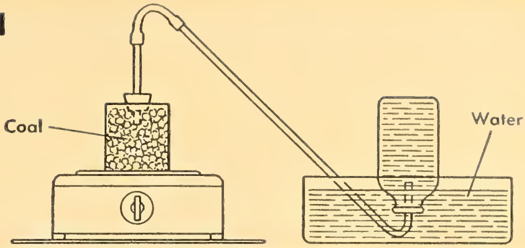
Although it is believed by many geologists that most of our important deposits of ore have been discovered, a great deal of effort is being made to locate new ones. Some geologists are using airplanes to aid them in observing, photographing, and mapping sections of the country difficult to reach by other means. The nature of the vegetation, the contour of the land, and the kind of rock formations, as well as their color, are clues to the presence of mineral deposits. Lamps which give off ultraviolet light and electronic and magnetic instruments also help to locate new ore deposits. (See picture facing page 185.)

Some geologists think that there may be valuable mineral deposits located at greater depths in the earth's surface than it has been possible to reach by modern mining methods. New methods may be developed which will make it possible to obtain minerals from these.

SUMMARY

The development of our country as an outstanding industrial nation has been possible largely because of our abundant mineral resources. These resources have been used without much thought about the future, and we are now confronted with a possible shortage of many important minerals. In order to prevent these shortages from becoming critical, we must: (1) improve the methods used for obtaining minerals from the earth; (2) discover ways of getting metals from low-grade ores; (3) avoid wastes; (4) develop substitutes; and (5) locate new deposits.

DEMONSTRATION



Generalization to be demonstrated. Fuel gas can be prepared from coal.

What you need. A tin can, such as a Sterno can that is made without solder; one-hole stopper; glass bottles or jars, as shown; water pan; rubber tubing; bent glass tube, as shown; source of heat, such as a gas burner or hot plate.

What to do. Fill the can with pea-size pieces of soft coal. Arrange the can and tubing as shown. Heat the can slowly at first, but gradually increase to full heat of the burner. Collect the gas in jars or bottles, cover the mouth of the bottle with glass plate and remove from the water. Collect as many bottles of gas as you can, and test them all to see if the gas in each will burn.

What to observe. Did the gas in all bottles burn? If the gas in your first bottle did not burn, can you explain why it probably did not?

What does it mean? What evidence is there that the coal has been changed? Would you say that this was a chemical change? Why can this be called a fuel gas? Would all kinds of coal yield fuel gas? How could you check your answer on this?

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words which should be substituted for the italicized ones to make the statement true.

1. Coal is a *fixed* natural resource.
2. With only 6 per cent of the world's population, the United States uses *6 per cent* of the world's minerals.
3. In 1952 coal furnished *54 per cent* of the energy obtained from mineral fuels and water power.
4. Much of the iron we need may, in the future, come from *higher* grade ore in the Mesabi Range.
5. *Modern methods of obtaining* oil from sources within the earth make most effective use of natural gas and water pressure.

CHAPTER ACTIVITIES

REVIEW YOUR UNDERSTANDING

Two important generalizations developed in this chapter are listed below. Following each is a list of statements which may or may not illustrate the application of this generalization. On your answer sheet, write the letters of those statements which illustrate the application of each generalization. **Do not write in your textbook.**

1. Water can be saved and soil erosion can be prevented by proper land management.
    - a. Eroded land in some places is being reseeded to grassland.
    - b. Alfalfa and clover are sometimes plowed under rather than harvested.
    - c. Farmers change the kind of crop grown on a plot of land from year to year.
    - d. Contour farming is often used in raising crops on sloping fields.
    - e. The average annual rainfall is not the same in all parts of the country.
2. The supply of our natural mineral resources is being used at a rapid rate.
    - a. About 34 per cent of the energy obtained from mineral fuels and water power in the United States was furnished from coal in 1952.
    - b. The number of automobiles in use in the United States is constantly increasing.
    - c. Oil is obtained by drilling wells into oil-bearing sands in the surface of the earth.
    - d. In the last ten years, the volume of gas sold to consumers has increased two and one-half times.
    - e. The amount of iron used per person in the United States has increased 250 per cent since 1900.

REACH A CONCLUSION

The following test contains two true statements headed *If,* and four conclusions headed *Then.* Only one of the conclusions is based upon an accurate interpretation of the two statements. Select the accurate conclusion in each part, and write its number in the proper place on your answer sheet.

If:

1. Steel contains a high percentage of the chemical element iron.

2. Another chemical element, manganese, is sometimes mixed with steel to harden it.

Then:

1. Steel is a chemical element.
2. Steel and iron are the same.
3. Steel cannot be made without manganese.
4. Some steel contains both iron and manganese.

Virginia Forest Services

These high school boys are learning about forest management, fire control, and reforestation, all important in the conservation of our national resources.

chapter 24 CONSERVATION OF LIVING THINGS

BESIDES our non-living resources such as soil, water, and minerals, there are many important living resources on the earth. The trees that grow in our forests, grasses on the grasslands, and wild animals supply us with many essential products and services. Human beings are also important resources who can contribute much to a country if the best use of their abilities is made.

The close relationship between our nonliving and living resources makes it impossible to deal with one without concern about the other. Trees, grass, and wild animals are dependent upon soil and water, although, as you have seen, the kind of soil and amount of water in the earth are also dependent upon the vegetation that covers the earth. Furthermore, the welfare of human beings is to a large extent determined by the way all of our resources are used.

PROBLEM 1. How are we using our natural supply of living things?

FORESTS AND GRASSES

As we have seen (page 434), early settlers found a great supply of natural resources: plants and animals enough to supply the settlers with food for themselves and their livestock, materials for clothing, and lumber for building. The vegetation protected the precious soil and helped to store water. With the increase in population, however, much land was cleared of natural vegetation, and food crops such as corn, wheat, and potatoes were planted. Larger herds of livestock were needed to meet the increasing demands for meat. Such expansion of farming and livestock operations is justified only as long as the land is being put to its best use.

Trees and grasses as natural resources. Forests and grasslands are each considered to be large communities made up of the different kinds of plants and animals that live there. As you can see below and on page 461, each community has one important type of plant life, grasses in grassland and trees in the forest.

Forests have developed where there has been enough rainfall to grow trees. But there must be more than just water for trees to grow and develop into a forest. There must be soil where tree seed can germinate, and where young trees can anchor themselves and obtain the minerals needed for growth. Trees then depend upon the living things that help form soil, and trees in turn hold back rain water and protect the soil from washing away, as shown on page 458. Trees also aid in forming soil. By carrying seed, animals help to propagate trees. Animals of the forest may in turn obtain food and shelter from the trees. These are only a few examples of how the forest becomes an interdependent community of living things.

Grasslands have developed in those regions where there is generally not enough rainfall to grow trees. Animals and other plants make their homes in the grasslands. As was true of forests, the living things of the grasslands are interdependent. Each benefits in some way from the other plants and animals that live there.

Before man disturbed the natural vegetation of this country, nearly one half the land area of the United States was covered with forests of more than

Many different kinds of plants and animals live in forest communities such as this, although trees are the important type of plants.

U.S. Forest Service

1,000 different kinds of trees. Equally as large an area is suitable for growing grasses. On millions of acres of land in southwestern United States, grass and trees grow together. This land produces both trees for lumber and feed for livestock.

How trees have been used. Although trees from our original forests were often destroyed to clear the land for farming, most of the trees have been harvested for lumber and other useful products. About 80 per cent of the houses and 95 per cent of the furniture in the United States are built principally of wood. Millions of wooden poles and railroad cross ties are produced each year.

Most of our paper is manufactured from wood. Over half of the rayon cloth and cellophane are made from wood by special processes. Many plastics used in making such articles as fountain pens, dishes, and combs are produced by combining certain chemicals with sawdust or wood flour. The products made from wood number in the thousands. About one tenth of the wood produced is still used for fuel.

Because of the way in which forests hold back water and slow down the melting snows, they help reduce floods, save soil, and regulate the flow of water in streams. Forests also provide recreational opportunities by way of fishing, hunting, camping, and hiking for millions of people in this country every year.

Fires, insects, and diseases. Fires, insects, and diseases damage or destroy about 2 billion cubic feet of wood each year. That is nearly twice as much wood as used in paper manufacturing each year. Nine tenths of all forest fires are man-made. Some harmful insects and diseases are usually present in any normal forest, although they generally do only limited damage. But occasionally, when conditions become favorable for the spread of certain tree diseases, great damage may be done in forests before the disease is brought under control.

American Forest Products Industries

Fire meters like this are used to inform the public of fire danger and to help prevent fires caused by man's carelessness.

The national forests offer opportunities for outdoor recreation such as camping.

U.S. Forest Service

Wasted lumber. Improper cutting of trees wastes valuable lumber. Large trees may be cut so that they fall on smaller trees and break them. Sometimes all trees are removed and none left to produce seeds. Occasionally only the better types of trees are taken and the poor ones left. If brush and broken trees are left scattered over the ground, the possibility of forest fire is greatly increased.

Our forests today. Today there are 622 million acres of forests in the United States. This amount of acreage represents about one third of the total land area of the United States. About 459 million acres of forest land are capable of producing valuable timber and other forest products. Three fourths of the forests are owned by private individuals and large corporations. The other one fourth of our forests belong to the public, most of them in national forests managed by the Forest Service of the United States Department of Agriculture. Today there are 151 national forests comprising over 181 million acres.

How natural grasses have been used. The dense natural grasses that the first settlers found in the central and western plains of the United States seemed sufficient to feed an unlimited number of cattle, sheep, and horses. As we have seen, this was not so. More livestock were put upon the grasslands than could be fed by the natural supply of grass. When this happens, the livestock kill the grass by eating it too close to the ground. Such *overgrazing* prevents the grasses from reproducing, thus destroying the natural growth. Without the dense mats of grass to hold it, rich topsoil is washed away with every heavy rain, or blown away by winds during the dry season, causing once densely covered grassy land to become a desert of drifting sands (see page 434).

Airplanes are used to fight insect pests which destroy crops. Here insecticides are spread by plane over an Oregon forest in the battle against insects.

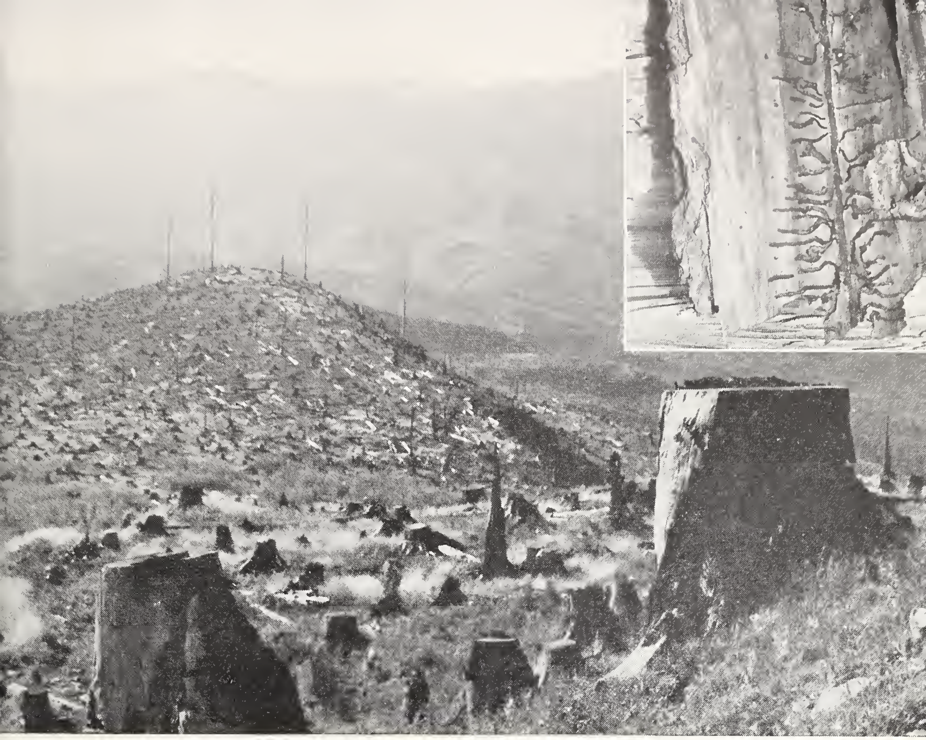
American Forest Products Industries

WILD ANIMAL LIFE

Man has used certain wild animals as a source of food. Clothing materials such as furs and hides have been obtained from other animals. The burrows of small animals and the dams built by beavers have helped conserve water. It has been estimated that birds save millions of dollars worth of crops and forests from being destroyed by insects each year.

How wild animal life has been used. Early settlers found buffalo roaming the western plains in great herds; there were probably 50 million of them, a seemingly limitless number. Buffalo meat was good to eat and the hides could be used for other purposes. As a result, buffalo were killed in great numbers year after year, until today there are no buffalo living in the wild state.

Antelope too were killed for food, and now only a few small protected



U.S. Forest Service

Three kinds of forest waste. This was once a magnificent forest of Douglas fir, but most of these trees were cut and forest fires destroyed the rest. The upper picture is an example of insect damage to trees.

herds are left. Other animals, such as the passenger pigeon, the Labrador duck, California grizzly bear, Merriam elk, Texas mountain sheep, Pacific white-tailed deer, have been completely killed off; there are no live ones left today—not even in zoos. Trapping and hunting have greatly reduced the number of fur-bearing animals such as the beaver.

Such slaughter of wild animals only partly accounts for their diminishing numbers. Another factor is removal of the type of plants upon which each kind of animal depends for feeding and for rearing its young. Clearing land for farming, and fencing in cattle ranches and wheat farms reduced the amount of grasslands available for the buffalo and antelope. When swamp lands were drained so that the land could be used to produce crops, birds and other animals that used the natural vegetation of the swamp for protection were forced to leave.

There are many interesting accounts of the great numbers of fish found by the early settlers along our coast and in our lakes and streams. But their numbers have been greatly reduced. There are so few sturgeon, shad, and Pacific halibut left that they may die out completely. Shellfish such as oysters and scallops have also suffered.

Streams once fed by forests now removed no longer carry enough water throughout the year to provide a home for fish. Dams constructed for hydroelectric plants have become barriers to the salmon that migrate up stream to rear their young. Soil washed away from eroded land makes streams and lakes too muddy for fish to live in. Waste products from factories have polluted some streams with acids and other chemicals that kill fish.

One should not jump to the conclusion that man should have left the forests, the grasslands, and wild animal life just as he found them originally. They were natural resources that he had to use in order to survive, although he has not always used them wisely. We can do nothing now to return the resources that have been wasted, but we can do something about the way our remaining resources are used in the future. Our next problem will help us understand how our natural supply of plants and animals can be used more wisely in the future.

Black bears are one group of wild animals that make their homes in forest communities.

U.S. Forest Service

SUMMARY

Many plants and animals have proved to be valuable natural resources for man. They have been used for food. Man has obtained materials from them for use in constructing homes and making many valuable articles.

Wild plant life in the prairies and forests has aided man by conserving soil and water. Since man has not always used these resources wisely, he is now threatened with a loss of many of the materials and services which they provided.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Before man disturbed the natural vegetation of the United States, the fraction of the total amount of land covered by forests was about (a) one tenth; (b) one fourth; (c) one half; (d) three fourths.
2. Today the part of the United States covered by forests is about (a) one tenth; (b) one third; (c) one half; (d) two thirds.
3. When too many livestock are allowed to feed on grasslands, there is danger of (a) food poisoning; (b) overgrazing; (c) water shortage; (d) over-eating.
4. From a study of the wildlife remaining in the United States, it is evident that (a) man should never have used any wildlife; (b) only the most desirable wildlife has been killed; (c) our natural supply of wildlife could be used more wisely; (d) from now on we should not use our natural supply of wildlife.

PROBLEM 2. How can we use our natural supply of living things more wisely?

MANAGEMENT OF FORESTS

Everybody's problem. If wood becomes scarce, its thousands of products also become scarce and more expensive. If forests are removed, floods followed by water-shortages become more common. If there is less grass on the plains to feed cattle and sheep, less meat will be produced. You'll either pay more for meat or eat less of it, as is now necessary in some countries of the world.

Even though you yourself may not hunt or fish, you will be affected if our natural supply of animal life continues to decrease. The outdoors will be greatly changed; it will be a less interesting place to spend your vacation. If there are fewer birds, you will have to help pay for the damage to crops caused by increased numbers of insects. You can supply other examples of how we would be affected by the loss of our natural supply of living things.

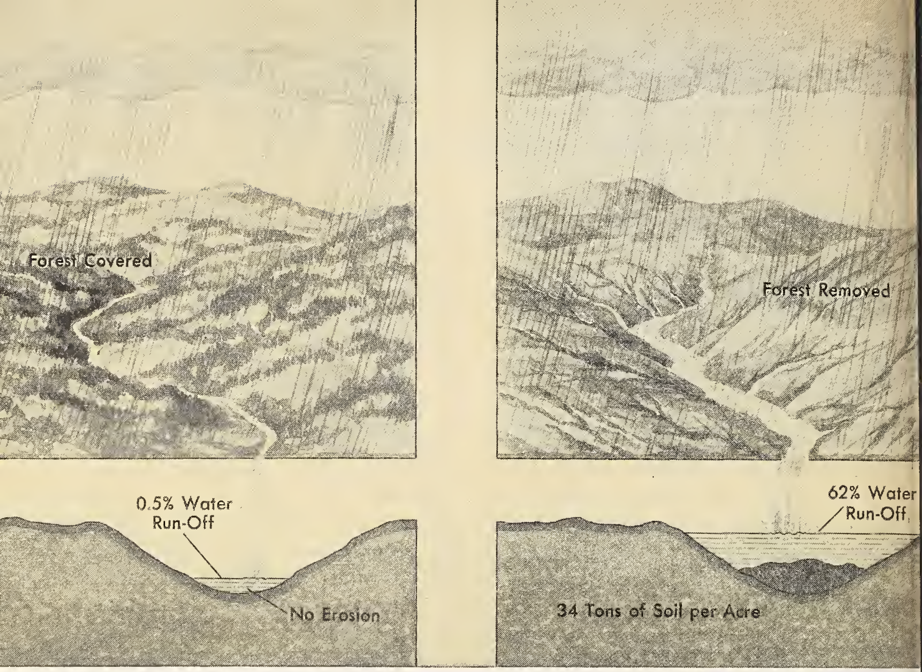
As good citizens, we should learn how our natural plant and animal resources can be used more wisely. We should then find ways to see that our resources are properly used and not wasted.

Protection of forests. Forests must be properly protected from fire in order to increase their production. To do this, it is necessary to maintain special lookout stations and to have available special fire-fighting equipment. Roads must be built so that men and equipment can be moved rapidly from one part of the forest to another. Records kept by weather bureaus are important to determine the speed and direction of the wind, the dryness of vegetation, and other factors which might have an effect on the spread of a fire. A well-protected forest must also have a telephone system between lookout stations and stations from which firefighters can be sent to fires. Strict enforcement of smoking and campfire regulations will help to prevent fires from starting, and wide lanes built across large forests make fires easier to control once they do start. New ways of fighting forest fires are being used, and others are being tested which may be improvements over the older methods.

In 1952, all but 10 per cent of the forests in the United States were under organized fire protection. About half of the losses from fire in that year was on these unprotected forests. Although great progress has been made in extending fire protection to more and more forests, an educated public opinion has helped reduce losses. The road sign on page 453 is only one of the many devices used by public agencies and the forest industries to educate the public.

Scientists have developed methods of controlling some of the most destructive forest insects and diseases (see page 454). More men and special equipment are needed to carry on the fight against these enemies.

Controlling the growth and cutting of trees. In order for a forest to continue to produce good quality trees, several things have to be done. The number and types of trees cut each year must be limited so that immature trees



Adapted from New Forest Frontiers

By actual measurements it has been found that less than one per cent of a 27-inch rainfall on forest-covered hills will run off into streams and that there is no soil erosion. On a similar area where the forest has been removed, 62 per cent of the water will run into streams, removing 34 tons of soil per acre.

are not cut, and good tree stock is left for reseeding. Where young trees cannot get started by natural seeding, they may have to be planted. If trees are growing so close together that none of them can grow well, they may have to be thinned out. The number of sheep or cattle allowed to graze in forests must be controlled to save young trees.

Better management of forests. Only about half our forests are considered to be well managed. There may be several reasons for the fact that most of the poorly managed ones are privately owned. Some owners find the expense of good practices too great; others lack the technical assistance needed to improve their practices. Wanting to get all they can out of their forests, owners may give no thought to the future.

Several things could be done to overcome this. Private owners could be aided by making it possible for them to borrow money at low interest for a long period of time, since it takes years to grow a crop of trees. Insurance should be made available against losses by fire, insects, and diseases. Taxes on forests should not be so great that the owner has to cut trees every year in order to pay them. Forest owners should also be able to get the best advice possible on ways to improve the management of their individual forests.

Reforesting idle lands. Forest surveys since 1920 clearly show that the gap between growth and drain is closing. Improved management practices and improved fire protection gives promise of greater growth than removal in forests in the years to come. However, the United States Forest Service estimates that 62,000,000 acres of private land in the United States is in need of replanting to trees. This includes both land which was cleared for agriculture and forest areas burned and denuded along with the seed source.

To date, there have been over 8,000,000 acres planted in the United States, more than half of it on privately owned lands. Some of the large industries in the West are planting their remote areas by seeding from airplanes. Tree-planting machines are taking much of the drudgery and expense out of this job which used to be done entirely by hand.

Farmers who want to replant idle lands on their farms can obtain tree seedlings at little or no expense from their State Forester or from the nearest forest industry forester. Reforestation activities are at an all-time high at the present time, but there is still a big job ahead.

MANAGEMENT OF GRASSLANDS

Reseeding farm land to grasses. There are millions of acres of farm land in the United States that should be reseeded with grass. These are places of very limited rainfall where the grasslands have been plowed and planted to crops.

After the dust-bowl years of 1934 and 1935, the federal government bought many of the worthless dust farms and encouraged the destitute owners to move to other sections of the country. Agencies of the United States Department of Agriculture undertook the tremendous task of planting grass on the idle land. Both natural and new-type grasses were used, grazing was carefully controlled, and water conserved by the best methods. As a result of these practices, the land on one of the large projects was brought back, in less than ten years, to its maximum production of grasses.

It has been demonstrated that growing grass is the wisest way to use the land in country where rainfall is too limited for crops. But during years when rainfall is plentiful, people forget the dust bowl. They buy land from private owners, plow the grass under, and plant crops again. The result of

Girls using weeding carts to help them in weeding tree seedlings in a large nursery that grows five million tree seedlings a year.

K. S. Brown

U.S. Forest Service

Firefighters, called smoke jumpers, in an airplane flying near a forest fire. When a signal is given the smoke jumper will parachute from the plane to a position near the forest fire. Firefighting equipment has already been dropped by parachute. Equipment (inset) for fighting forest fires, is stored in large wooden cabinets. Cabinets are placed in various locations throughout the forest.

such practices is shown in the picture on page 434. Is this the wisest way to use these lands?

Controlling overgrazing. The number of livestock that can be grazed on a definite area of grassland without overgrazing it is called its *carrying capacity*. By preventing the number of livestock from exceeding the carrying capacity of a piece of land, it is possible to prevent overgrazing. Because livestock eat the heads of grasses, they should be kept off the land until the grasses form seed.

When grasslands become overgrazed, livestock should be removed and the land reseeded. If enough of the native grass is left, the land may be reseeded naturally. In extreme cases where overgrazing has killed practically all grass, it is necessary to plant grass seed. It may take two or more years for the young grass plants to become established, during which time no livestock should be allowed to graze on the land.

MANAGEMENT OF WILDLIFE

Increasing wild animal life. Our natural supply of wild animal life can also be increased by proper management. Natural shelter and food must be provided. Whenever animals cannot reproduce rapidly enough to restock themselves naturally, it may be necessary to provide special protection for them. Game animals such as fish and quail may have to be reared in hatcheries or on special farms in order to maintain an adequate supply for fishermen and hunters. (See the picture on page 463). We have already seen how the destruction of forests and grasslands practically eliminated the wild animals that once lived there.

When trees and grasses are planted on idle lands, more homes and more food will be available for wildlife. Reforestation and regrassing will decrease the pollution of streams from soil erosion. There will be a steadier flow of clear water in streams so that fish can grow and reproduce more fish. There will be fewer floods in the lowlands to destroy wildlife, their homes and food.

Protected areas for wildlife. Our federal government through the National Park Service has set aside certain federal lands where plants and animals are left to develop naturally. These include Great Smoky Mountains National Park in North Carolina and Tennessee; Yellowstone National Park in Wyoming, Montana, and Idaho; and Acadia National Park in Maine. Although fishing in the streams of the national parks is permitted during certain times of the year, hunting is prohibited. Tourists visiting the parks are not allowed to pick wild flowers or to remove any other vegetation. By such restrictions the National Park Service is attempting to maintain natural conditions for the wildlife in the parks.

State and national game regulations. Each state has some organization such as a game and fish commission that is responsible for managing the wild game in the state. The commission conducts surveys to determine the number of each type of wild game in the state, and recommends laws to insure the best use of that game.

After determining how much wild game can be supported in different sections of the state, most of the commissions raise large numbers of birds and fish and release them into their natural homes. In this way the com-

Beef cattle on a well-managed range where only as many cattle are allowed to graze as can be properly fed without destroying the grass. The owner will earn a greater profit from these cattle than he would from a larger number of cattle on the same range.

U.S. Forest Service

mission attempts to keep wild game of the state up to a maximum so that some will be available for hunters and fishermen every year.

Our federal government through its various agencies regulates the use of some of our natural resources. Seal are protected by federal law. The hunting season on ducks as well as regulation of fishing in coastal waters of the United States is now controlled by the federal government.

Game management and the balance of nature. An understanding of the *balance of nature* is important in game management. Under natural conditions there is generally a balance between the number of wild animals and the amount of food they need. For example, deer feed upon plants in the forest, and mountain lions feed upon deer. If the mountain lions were killed off, the deer would increase in such numbers that there would not be enough plant food for them. Some of the deer would starve to death until they decreased to the number that could live on the food supplied by plants. Again there would be a balance between the number of deer and the amount of food available for them. Coyotes naturally feed upon rabbits and other small animals. If their natural supply of food becomes low, they may kill chickens and young sheep. When this happens, man generally considers coyotes pests and destroys them. With their natural enemies killed, rabbits, mice, and gophers increase in numbers and become worse pests than the coyote. Good game management is based upon a consideration of the balance of nature and practices are avoided that would interfere with this balance.

Elk being fed on a wildlife refuge during the winter when it would otherwise be impossible for them to obtain enough food.

U.S. Fish and Wildlife Service

SUMMARY

Every American should be concerned about the way our natural supply of living things is used. Forests and grasslands should be managed so that no more plants are removed than can be replaced year after year. Idle lands suitable only for growing trees should be planted and properly managed to insure a continuous production of forest products. Where there is insufficient moisture to grow other kinds of crops, grasslands should be left undisturbed for the production of grass.

Wild animals are dependent upon plant coverage for food and protection. Wherever plant coverage is removed the number of wild animals decreases. Good game management is based upon the maintenance of a proper balance between game animals and their natural food supply.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words which should be substituted for the italicized ones to make the statement true.

1. Good game management is based upon a consideration of the *balance of nature.*
2. In 1952, *20* per cent of the forests in the United States were unprotected.
3. If trees are growing too close together, they should be *burned.*
4. Tree-planting machines *decrease* the cost of planting tree seedlings.
5. Growing *grass* is a wise way to use land in the plains country where the rainfall is limited.
6. Livestock should be removed from overgrazed land and the land *reseeded.*

U.S. Fish and Wildlife Service

Ducks on a wildlife refuge where they are protected and encouraged to raise their young.

PROBLEM 3. How can human resources be used more wisely?

INHERITED CHARACTERS

Human beings are also a part—and the most important part—of the resources of our country. Farmers, miners, factory workers; doctors, homemakers, librarians; policemen, teachers, writers; boys and girls—all these people do special work to make our country what it is today.

Relationship of heredity to human abilities. Look at the members of your class. No two of you look exactly alike. Your faces are different; your voices are different; and the sizes and shapes of your bodies differ to some extent. You also differ in many other ways, and many of these differences are accounted for by your inheritance.

Although it has been more difficult to study heredity in human beings than in other living things, it has been shown that people inherit many of the characters they possess in a manner

Henle from Monkmeyer *Merrim from Monkmeyer*

The magazine publisher, the secretary, and the farmer all possess abilities and special training which make them valuable human resources.

similar to that described in Chapter 22. Through a study of many generations of family histories, it has been possible to determine some of the human characters that are inherited. The color of eyes, facial features, head shape, height, and many other physical characters have been found to be inherited.

As you will recall, actions and behavior are controlled by the nervous system. The kind of nervous system a person has, therefore, will to a large extent determine his special abilities. Although characters of the nervous system are much more difficult to study than such physical characters as eye color, it is believed that many of them are inherited. For example, it has been shown that some observable forms of mental deficiency, idiocy, and a type of deafness, caused by defective *auditory nerves,* occur in some families more often than in other families. This and other such evidence have been accepted as indicating that these characters are also inherited. In a similar manner it has been shown that the many characters which determine intelligence are also inherited. A person does not inherit a special ability, such as musical ability, as such, but he may inherit the many characters which make it possible for him to develop the ability.

You should not necessarily assume, because you find it difficult to do some things, that you have not inherited the characters which give you that special ability. The first time you ever put on a pair of roller skates you probably had difficulty, but this did not mean that you could not become a skater. Some young people who really wanted to become good skaters worked hard at it and through long hours of practice have become experts. The same is true in other sports, in art or music, in school work, and in various other activities. On the other hand, some people may want to become expert in some activity and work very hard at it, but because they lack the inherited characters required they never achieve their goal.

It should be remembered that each human being possesses inherited characters which cause him to be similar to other human beings in some ways and yet quite different from them in other ways. This means that each human being is a special kind of person.

MISUSE OF HUMAN RESOURCES

How have we used the special abilities of people? Many of our valuable human resources are being misused just as surely as our natural resources have been—by neglect or poor management or failure to understand how best to use them.

Illiteracy. One of the causes of such waste is the lack of good educational opportunities. During World War II, it was discovered that a number of our soldiers were *illiterates;* that is, they could neither read nor write. In the army they were taught these skills in a comparatively short time, proving that it was merely lack of schooling that had wasted their abilities.

Many of the people who can read or write, however, are also misusing valuable resources, because they have not received enough education or the kind they needed to help them to develop properly.

Vocational misfits. When people are employed in work for which they are not fitted, human resources are being used unwisely. Such people, called *vocational misfits,* may possess unusual abilities along some lines, but have

The housewife and the factory worker are important human resources because of the way they use their abilities.

Roy Pinney from Monkmeyer

Kayfets from Monkmeyer

drifted or been forced by the necessity to make a living into the kind of work for which they are unfitted. Only by allowing them the opportunity to discover their special abilities and to receive training in the kind of work where these abilities can be used, will we be using them to best advantage, and at the same time making them happy people.

Other people misuse their natural abilities when they violate the law and take advantage of others. We are not using human resources wisely until we search out and eliminate the conditions causing crime and *delinquency*.

Accidents and illness. Deaths from violence, chiefly accidents, is the most common threat to teen-age life, according to one of the large insurance companies. Motor vehicles are the leading cause of accidental death among teenagers. Among boys, drowning ranks second, and firearms third. Falls are the most common type of disabling accident among all of the people. Burns, sports, poisoning, and falling objects are some other leading causes of accidents. It is important for people to understand that each accident has a cause. Accident rates in some factories have been greatly reduced by instructing workers about the causes of accidents, and teaching them how to avoid situations that lead to accidents.

This young lady is being given instruction in how to drive an automobile, as part of a high-school course she is taking.

Colorado State College of Education

Illness too causes an enormous waste of resources. Not only is the expense of caring for the ill high; the greatest loss results from people not being able to use their abilities for productive purposes during the time they are ill. Remarkable progress has been made in preventing certain diseases, but a number of them have not been successfully controlled. Cancer is such a disease, and the leading cause of death from disease among teenagers.

WISE USE OF HUMAN RESOURCES

Educational opportunities. Providing better schools is one way to reduce illiteracy. Special classes for normal adults, suggested by the army experience with illiterates, would be another step toward using human resources wisely.

Schools can also play an important part in reducing the number of vocational misfits. By helping young people to discover their special abilities and preparing them to use these abilities in their work, schools could contribute enormously to the productiveness of human beings.

USHA photos by Oliver and Sekaer

Undesirable living conditions, as shown at left, represent one misuse of human resources. More modern, up-to-date home units, providing light, air, and protected areas where children can play, give boys and girls a better chance to develop mentally and physically.

Prevention of juvenile delinquency. Poor home conditions, undesirable associates, lack of educational opportunities and recreational facilities, and inability to get employment all contribute to crime and delinquency. Some of them can be eliminated.

Good schools educating boys and girls to take their places in the world would help to overcome delinquency. The home life of many families cannot be happy or healthy because of the kind of buildings in which they must live. As long as all the people of this country, whether they live in cities or in rural areas, do not have clean and wholesome homes, with modern sanitation and adequate light and air, human resources will not be used to best advantage. Some cities have built modern home units to replace undesirable housing; more such projects are needed.

Recreational and work activities to meet the needs and interests of boys and girls should be provided by schools. Development of supervised recreational programs in all communities would give young people desirable ways to spend their spare time. Employment agencies operated by schools could help students to find part-time jobs.

Prevention of accidents. Automobile accidents may be caused by poor driving, faulty automobiles, bad roads, or careless *pedestrians.*

Merely knowing how to operate an automobile does not insure safe driving; neither does a knowledge of traffic regulations. To obtain a driver's license, a person should not only demonstrate ability to drive a car, but should show that he has no physical defects such as poor eyesight or bad

Colorado State College of Education

Boys receiving instruction in the proper care and safe use of guns in a high-school class.

hearing that would make him an unsafe driver.

Automobiles are being built with more safety devices each year: all-steel bodies, shatter-proof glass, easily operated controls, puncture-proof tires, good brakes, special signal lights. In order to make the best use of safety controls on your car, you must check them regularly to be sure they are operating at maximum efficiency.

Roads too are greatly improved each year, but many are still narrow and winding, and there are dangerous intersections where drivers must take special precautions to avoid accidents.

Pedestrians also have a responsibility for avoiding accidents. Most pedestrian accidents could be eliminated if people took special care to cross streets only at intersections, watched traffic lights, and checked traffic before crossing if there are no lights. If it is necessary to walk on the highway, walk always on the left side of the road, facing oncoming traffic.

If bicycles were subject to the same traffic rules as automobiles, many accidents might be prevented. Traffic signals are as important for bicycle riders as for automobile drivers. It is up to bicycle riders to reduce the number of accidents by observing all precautions in traffic, by equipping their bicycles with lights for night riding, and by keeping their bicycles in good mechanical condition.

Safety in the home. Most accidents happen in the home. There we spend most of our time, engaged in a variety of activities. Cooking meals and housecleaning; operating all kinds of home appliances such as irons, fans, and washing machines; bathing and shaving; climbing stairs and playing games—these are common types of home activities. In doing these things, people fall down stairs, slip on waxed floors, trip over playthings scattered on the floor, hurt themselves on electrical appliances.

Most such accidents could be avoided by a little care. Stairways should be kept clear and well-lighted; small rugs on polished floors should have non-skid mats under them; tools and toys should be put away when not in use; directions for operating household appliances should be carefully followed.

Safety in sports. Everyone who engages in sports such as swimming, hunting, fishing, skating, skiing, and many others should be acquainted with the accident hazards and know how to prevent them from causing accidents. Skill in any sport requires a knowledge of how to avoid accidents.

First aid. In cases of serious injury, a doctor should be called immediately; but the life of an injured person has often depended upon someone's knowing what to do before the doctor arrived.

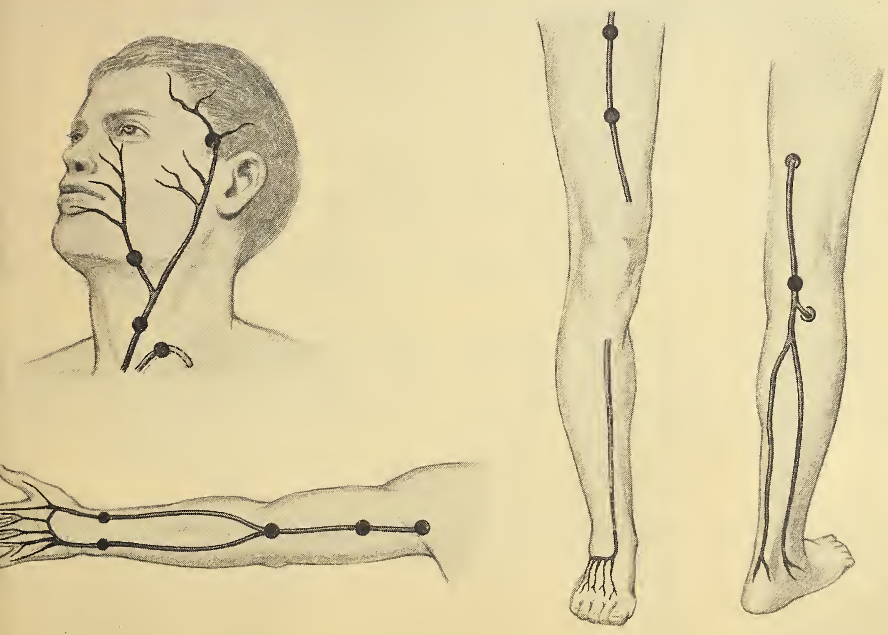
A well-stocked first-aid kit should be kept handy in every home, school, factory, office, automobile, and other places where accidents occur. Standard kits contain directions for using materials, but that is not enough. Everyone should learn by actual practice the techniques of first aid.

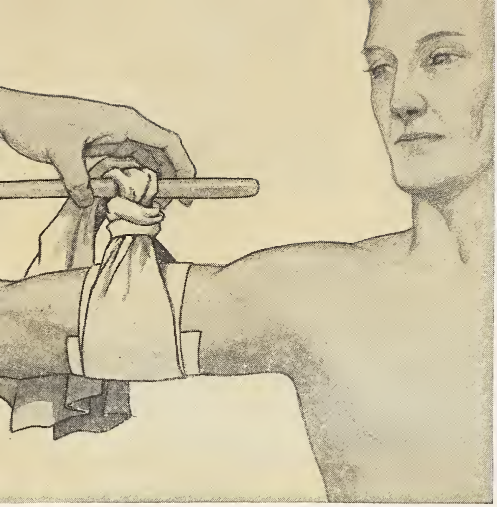
One of the important things to know is how to stop bleeding, since wounds are common types of injuries in accidents, and excessive bleeding from an artery can be dangerous. See below for the points in the body where pressure should be applied to prevent bleeding. Although such pressure may be applied with the finger, special constricting bands called *tourniquets* can be used effectively on certain parts of the body (see page 470).

Bleeding should be encouraged in minor scratches and cuts, since the blood will help wash away harmful bacteria. A cloth soaked with alcohol or a solution of salt may also be used to wash the dirt from a cut or scratch, and tincture of iodine may then be applied at the surface of the wound. A clean cloth wrapped around the wound will prevent dirt from getting to it.

Burns too need prompt treatment. For severe burns a doctor should be called immediately. Less serious burns

To stop bleeding from arteries, pressure should be applied at these spots on the body nearest to the wound, but between the wound and the heart. To stop bleeding from a vein, pressure should be applied to the spot nearest the wound but away from the heart (not shown).





A tourniquet should be tightened on the pressure spot only enough to stop bleeding.

may be treated by applying a burn ointment. Burn ointments of several kinds can be purchased at the drug store. It is wise to consult your doctor about what burn ointment to buy.

Persons with broken bones should be treated by a doctor. The injured part should not be moved until the doctor has treated it.

Gas poisoning, drowning, and electric shock are accidents which may cause death if *artificial respiration* is not applied immediately to the injured person. It is a method used to restore normal breathing in accident victims whose breathing has stopped. On page 471 you can see the way artificial respiration should be applied.

First aid for atomic radiation victims is a problem calling for special training.

Prevention of illness. In spite of the great advances made in medical science (as you learned in Chapter 18), there are still a number of diseases or illnesses for which the causes are not known. Cancer is such a disease. It kills more people each year than any other disease except diseases of the heart. Methods of treating some types of cancer have been developed, but there are others, such as *leukemia* (an overproduction of white blood cells) for which no sure treatment is known. Scientific investigations of cancer are being conducted in many laboratories, but an effective method of preventing the disease will probably not be developed until its cause is known.

The common cold, from which 94 per cent of all people in the United States suffer each year, is another disease for which a cure has not been found. Believed to be caused by one or more viruses, it is transmitted from person to person. One of the best known methods for controlling it, therefore, is to avoid association with people having a cold.

More laboratories and scientists are needed to solve the many problems involved in learning the unknown causes of some diseases and methods of curing or preventing them.

A number of agencies are organized to promote the study of human diseases and methods of control. The National Institutes of Health, of the United States Public Health Service, carry on research of great importance in discovering how many human diseases can be prevented and cured. The cost of operating the laboratories of the National Institutes is paid from funds of our federal government. National organizations, such as the American Cancer Society, the American Heart Association, the Tuberculosis and Public Health Association, and the National Foundation for Infantile Paralysis, raise funds and support the scientific study of certain diseases. A number of private foundations, supported with money contributed by individuals, also sponsor the study of diseases and ways to prevent illness. Many scientists in colleges and universities as well as scientists in laboratories maintained by industry devote a great deal of their time to learning about diseases and ways they can be controlled. Although millions of dollars are spent each year in medical research, many millions

1. Place the subject face down. Bend his elbows and place the hands one upon the other. Turn his face to one side, placing the cheek upon his hands. Kneel on either knee at the subject's head. Place one knee at the side of the subject's head; place the opposite foot near the elbow. Place your hands upon the flat of the subject's back in such a way that the heels lie just below a line running between the armpits. With the tips of the thumbs just touching, spread the fingers downward and outward.

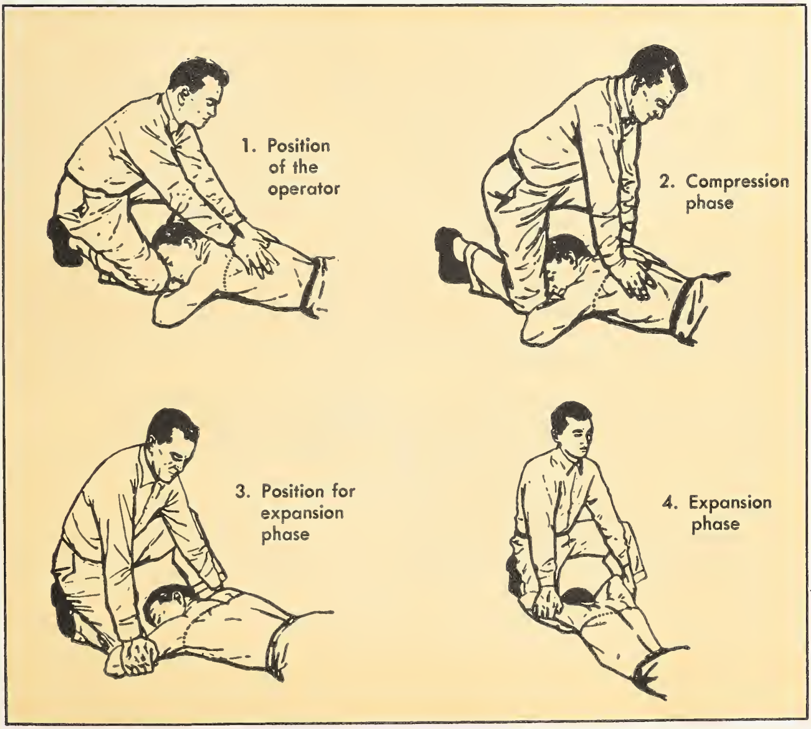
2. Rock forward until the arms are vertical. Allow the weight of the upper part of the body to exert slow, steady pressure downward upon the hands, keeping elbows straight. This forces air out of the lungs.

3. Release the pressure, avoiding a final thrust, and begin to rock backward slowly. Place your hands upon the subject's arms just above his elbows.

4. As you rock backward, keeping your elbows straight, draw his arms upward and toward you until you feel resistance at the subject's shoulders. Lower the arms to the ground. This completes the cycle. The arm lift expands the chest and forces air into the lungs.

Repeat cycles 12 times per minute at a uniform rate. Compression and expansion phases should be of equal duration; release periods should be brief.

The American National Red Cross



more are needed in order to carry on these extremely important studies.

The work of many health agencies today is directed toward the prevention of diseases and the treatment of those who are ill. As we have previously seen, state, county, and city health departments are concerned about the improvement of community health.

SUMMARY

The human resources of our country are the people who live here. In order for the human resources to be used most effectively, abilities of individuals must be discovered, and they must have opportunities through the home and community educational agencies to develop their abilities in desirable ways.

Accidents and illness are a great expense to the American people and frequently prevent them from engaging in socially desirable productive activities. By discovering their causes and taking the necessary action to remove those causes, such accidents and illness can be prevented. Effective programs for the conservation of human resources depend upon the education and co-operative efforts of all people concerned.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. An illiterate person is one who (a) cannot learn to read or write; (b) can neither read nor write; (c) has never been to high school; (d) was born in a foreign country.
2. The most common threat to teenage life is (a) heredity; (b) illiteracy; (c) accidents; (d) cancer.
3. Most pedestrian accidents could be eliminated if people would (a) move faster when crossing a street; (b) cross streets only at intersections with the traffic light; (c) walk on the right-hand side of the road; (d) wear dark colored clothing so they can be more easily seen.
4. Bleeding from a cut artery (a) is never serious; (b) should be encouraged; (c) is sometimes reduced with a tourniquet; (d) should be disregarded.
5. The situation which is *least* important in using our human resources more wisely is (a) the average height of the people; (b) vocational unfitness; (c) the health of the people; (d) accidents.

CHAPTER ACTIVITIES

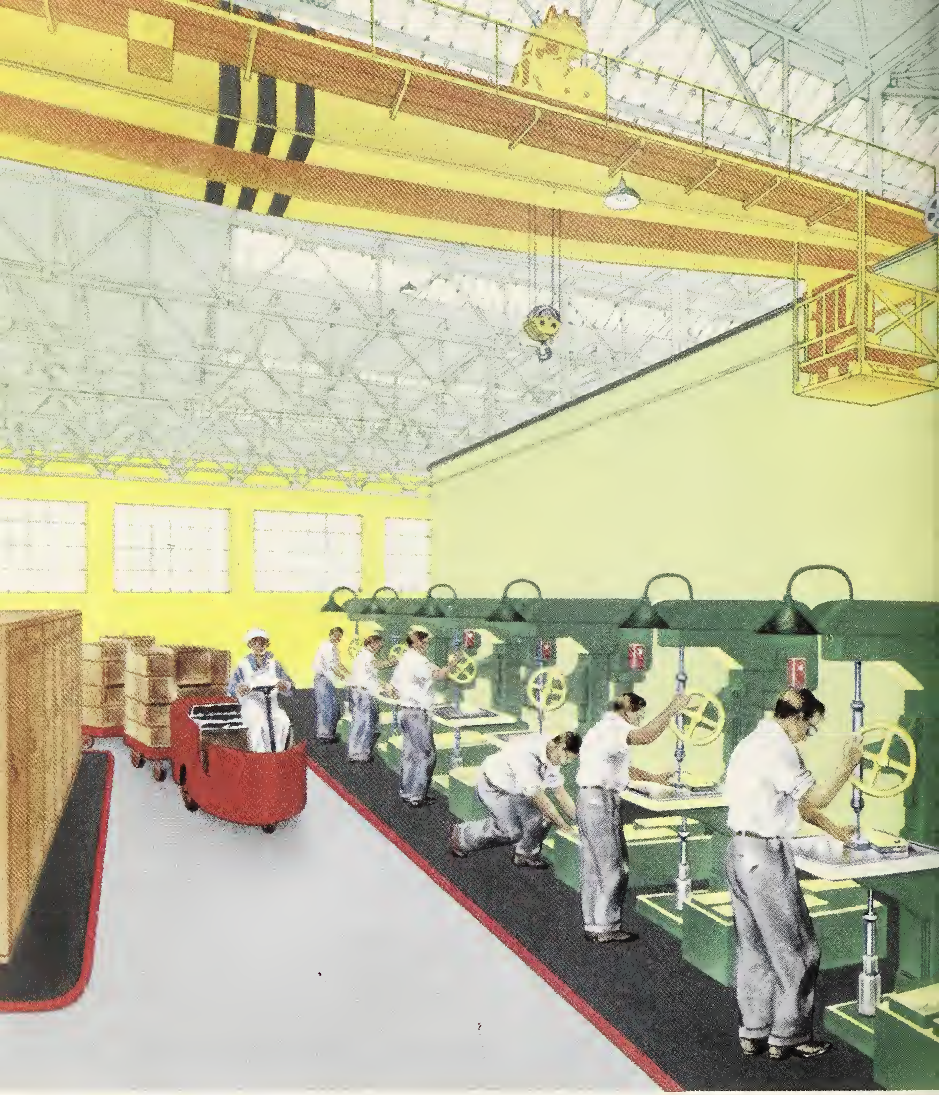
REVIEW YOUR UNDERSTANDING

Four important generalizations developed in this chapter are listed below. Following each is a list of statements which may or may not illustrate the application of this generalization. On your answer sheet, beside the number of the generalization, write the letters of those statements which illustrate the application of that generalization. **Do not write in your textbook.**

1. Many living things have been used unwisely.
   - a. A great many articles are made from wood.
   - b. Many rivers overflow their

Pittsburgh Plate Glass Co.

Not only are factories without color dreary; they are also less safe than those with color since light is poor, and dangerous moving equipment is not easily distinguished from the rest of the equipment in the room.



Pittsburgh Plate Glass Co.

Proper use of color helps prevent accidents. The factory shown above has been made safer by use of red lines to indicate traffic lanes, yellow for the overhead moving equipment, red for switches on the green machines. Such easily visible colors attract attention to possible danger spots in the room.

banks when rain is plentiful.

c. The grass which once grew on many acres of land has been replaced by plants valueless as livestock feed.

d. Since fish cannot reproduce naturally as fast as they are taken from lakes and streams, man propagates them.

e. Many swamps have been drained and the vegetation removed from the land without other protection being provided for wildlife.

2. An attempt is being made to replace forests and grasslands as fast as they are removed.

a. Tree seedlings can be obtained from state foresters.

b. Millions of tree seedlings are planted by farmers each year.

c. Millions of trees die each year from diseases and insects.

d. Overgrazed land is often reseeded.

e. Livestock furnish meat for millions of people.

3. Maintenance of proper balance between game animals and their food supply is important in game management.

a. Many streams are stocked with fish raised in hatcheries.

b. When deer become more plentiful some states extend the length of the hunting season.

c. Surveys are often made to determine the number of each type of wild game in a given area.

d. Hunting and fishing are popular with millions of people.

e. The cost of a hunting and fishing license is not the same in each state.

4. An effective program for conservation of human resources provides opportunities for people to make the best use of their abilities.

a. Illiterates are people who can neither read nor write.

b. Vocational counselors help people determine the kinds of work they can best do.

c. Automobiles are being built today that are more powerful than ever.

d. Supervised recreational programs help young people learn how to use their spare time in the most desirable manner.

e. Many national organizations have been founded to carry on scientific studies of ways in which certain diseases can be cured or prevented.

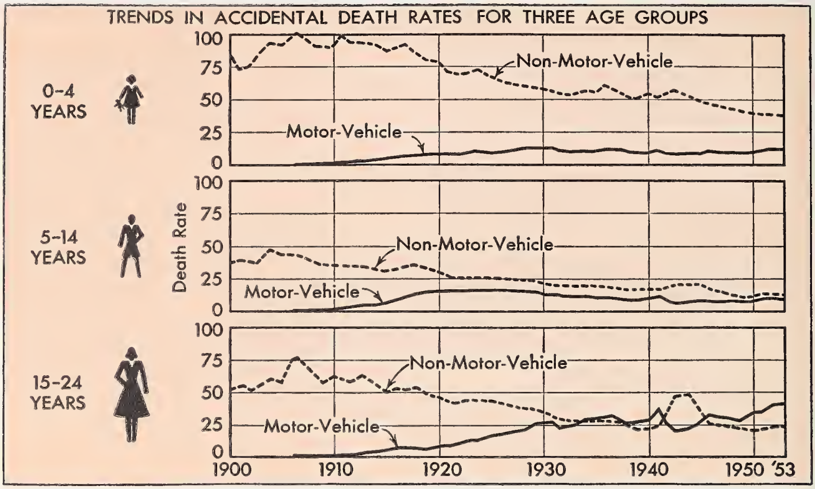
INTERPRET A GRAPH

On the next page are graphs showing trends in accidental death rates from 1900 through 1953 for three age groups. On your answer sheet, mark each of the following statements with a **T** if the graphs contain enough information to make the statement *true;* **S** if the graphs do not contain enough information to make a decision about the statement; and **F,** if the graphs contain enough information to make the statement *false.*

1. More people in the 15-24 years group were killed by motor-vehicle accidents in 1953 than in any one of the earlier ten-year periods.

2. More young people in the 5-14 years group were killed by non-motor-vehicle accidents than by motor-vehicle accidents.

3. Motor-vehicle accidental deaths among twenty-six-year-olds have in-



creased during each ten-year period from 1910 to 1950.

4. Non-motor-vehicle accidental death rates reached their peak before 1920 for children up to five years of age.

5. Non-motor-vehicle accidental death rates were higher in 1953 than motor-vehicle accidental death rates in the 15-24 years group.

6. During none of the ten-year periods reported in these graphs was motor-vehicle accidental death rates higher than non-motor-vehicle accidental death rates for young people through fourteen years of age.

7. More fifty-year-olds are killed by automobiles than any other cause.

8. In 1930 in the 15-24 years group there were more motor-vehicle accidental deaths than non-motor-vehicle accidental deaths.

9. The accidental death rate for elementary or grade-school children in 1953 was lower than in 1910.

10. Most motor-vehicle accidents are caused by automobiles being driven faster than the legal speed limit.

UNIT ACTIVITIES

APPLY YOUR KNOWLEDGE

A number of problems relating to the conservation of our natural resources are listed below. Beneath each problem are listed activities which may or may not be one way of helping solve the problem. On your answer sheet, beside the number of the problem, write the letters of those activities which might help solve that problem.

1. How can the erosion of topsoil by water be decreased?
   a. Contour farming
   b. Better seed selection

    c. Building check dams in gullies
    d. Fertilizing soil
    e. Reforestation
    f. Reseeding bare grassland

2. How can water be used most effectively for growing crops?
    a. Planting grass
    b. Contour furrowing
    c. Summer fallowing
    d. Planting trees
    e. Building check dams in gullies
    f. Crop rotation

3. How can our supply of mineral resources be saved?
    a. Avoiding waste in the use of materials
    b. Preventing mining accidents
    c. Developing better mining methods
    d. Burning fuels more economically
    e. Developing more new products
    f. Saving and using scrap metals

4. How can our human resources be used more wisely?
    a. Increasing the opportunity for education
    b. Helping people discover, develop, and use their special abilities
    c. Cutting down the use of materials
    d. Carrying on scientific research on disease
    e. Decreasing the number and seriousness of accidents
    f. Making each person responsible for himself only

CONDUCT INVESTIGATIONS

1. Find out what is being done in your community to save scrap metal, waste-paper, and other materials.

2. Make a survey of the farming area around your community to see what conservation practices are being used.

3. Find out what opportunities exist in your community for people to discover their special abilities and to learn how to use them most effectively.

4. Survey your community for accident hazards and suggest a program for making the community safer.

5. Keep a record of absences from your class or the entire school and determine how many were caused by illness.

REPORT ON CONSERVATION

1. Hydrology, the science of underground water and its use
2. Watershed management
3. Beneficial birds of prey
4. Scientific control of insects
5. *Keep Green* campaigns sponsored by the forest industries
6. The safety record of industry; safety in industry
7. The work of your state game and fish commission
8. Food and Agriculture Organization of the United Nations
9. World Health Organization of the United Nations
10. Soil Conservation Service of the United States Department of Agriculture

CONSERVE NATURAL RESOURCES

1. Conduct a scrap drive. Money obtained from sale of scrap materials could be used for school needs.

2. If tent caterpillars are destroying trees near your school, carry out a campaign to destroy them before they leave their "tents."

3. Sponsor a bicycle safety campaign.

4. Conduct a campaign to remove accident hazards from your homes. Locate as many as you can, see that they are removed, and make a class report on the results of the campaign.

5. Prepare posters to make students aware of the home accidents that cause most deaths among young people of your age.

6. Plan an assembly program that will help others in the school understand how they can help conserve natural resources.

READ ABOUT CONSERVATION

Allen, D. L. *Our Wildlife Legacy*. New York. Funk and Wagnalls Co., 1953.

The basic principles of wildlife conservation in the United States are presented along with discussion of what has been done about them.

American Red Cross First Aid Textbook for Juniors. Philadelphia: The Blakiston Company, 1949.

A textbook to serve as the basis of a course in first aid which when studied under an authorized teacher will qualify you for a certificate issued by the American Red Cross.

Bruere, Martha Bensley. *Your Forests*. Philadelphia: J. B. Lippincott Company, 1945.

An interesting account of the extent of our forests, how they are used, and how they can be used more wisely.

Butcher, Devereux. *Exploring Our National Parks and Monuments*. Boston: Houghton Mifflin Company, 1951.

A pictorial guidebook to our national parks and national monuments, with many interesting facts about the origin of the National Park System, how the parks are cared for, and the kind of enjoyment it is possible to realize from them.

Gabrielson, Ira. *Wildlife Refuges*. New York: The Macmillan Company, 1943.

A description of the wildlife refuges in the United States.

Guide for Self-Help and Neighbor Help for the Injured. New York State Department of Health. 1951.

A guide to first aid treatment, prepared for the New York State Civil Defense Commission.

Gustafson, A. F., Ries, H., Guise, C. H., and Hamilton, W. J., Jr. *Conservation in the United States*. Ithaca, New York; Comstock Publishing Company, 1949.

A complete reference on conservation for the use of young people.

New York State Civil Defense Commission, *You and the Atomic Bomb*. New York, Life Magazine, Dept. E, 1950.

A 32-page illustrated pamphlet about ways to protect yourself, and first aid treatment for the effects of the bomb.

Tenbergen, Niko. *The Herring Gull's World*. New York: Frederick A. Praeger, 1954.

A study of the social behavior of birds is presented in a most interesting manner.

Van Dersal, William R., and Graham, Edward H. *The Land Renewed: The Story of Soil Conservation*. New York: Oxford University Press, 1946.

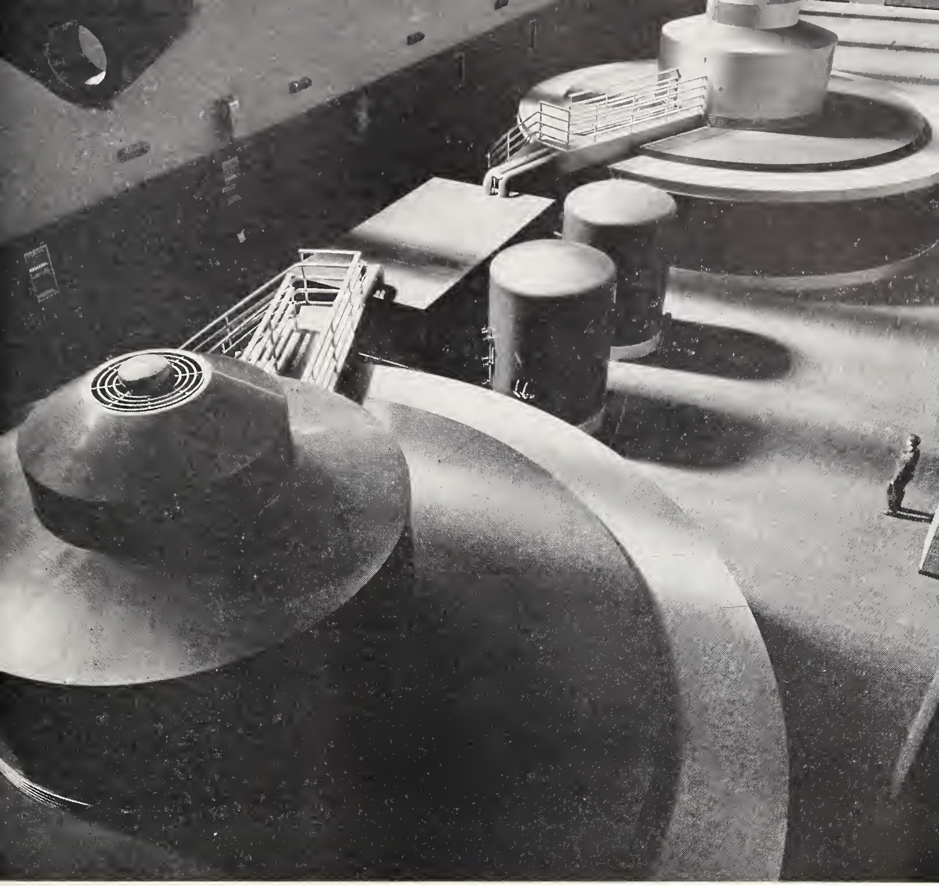
An excellent, well-illustrated book on practically every aspect of soil conservation, written for young people.

Van Dersal, William R., and Graham, Edward H. *Wildlife for America*. New York: Oxford University Press, 1949.

A book for young people on what we have done and what we need to do with our wildlife resources.

Yahraes, Herbert. *Make Your Town Safe*. Public Affairs Pamphlet. New York: Public Affairs Committee, Inc., 1947.

You will get many ideas from reading this pamphlet about how you and others in your community can prevent accidents and save human lives.



Tennessee Valley Authority

Geometric machines are designed by man to produce electricity. These machines in Pickwick Landing Dam powerhouse help TVA produce more than 15 billion kilowatt-hours of electric energy annually.

unit 11 WORK AND POWER

BECAUSE of the way in which our civilization is able to use power, the time in which we live is often called the Age of Power. The name is fittingly applied, for everybody nowadays uses more power in daily living than most kings could bring together even for an emergency, such as a battle, in the old days. When steam power began to be used, and even as recently as fifty years ago when automobiles were first used, horses were the only standard of power—horses for war, horses for hauling wood, horses for travel on the roads. We are reminded of this because the people who first began to work with power took the "horse"—not an actual horse, but an ideal universal creature who never got tired—as their unit of measurement, so that nowadays we speak of an automobile as having a hundred horsepower. Only a very rich man could own a hundred horses, in any country at any time of history, but the 100-horsepower engine is driven by people of quite ordinary income. The pilot of one of the largest airplanes has horsepower at his finger tips, which is more in one machine than kings of old had in a whole army's military machine. The farmer with his mechanized farming, the housewife who uses electric appliances, the passenger on a ship or train, the man who works in a factory, the boy who rides a motorbike, all use power and enjoy the results of its use.

To obtain such large amounts of power, modern man has drawn almost too heavily on readily available sources of energy—such as coal, oil, and falling water—to operate his machines. Scientists are now exploring ways to control and use a newly discovered source of power, atomic energy. At the same time, they are deeply interested in using as efficiently as possible the sources of energy which we already have so that in the future we shall have both the present sources and atomic energy to draw on.

In this unit you will learn what sources of energy are available to man and how he uses them to run his machines. You will also learn of some of his successes with atomic energy as well as some of his hopes for its future use.

Godsey from Monkmeyer

The potential energy of the bent bow will soon give the arrow kinetic energy (see page 481) of motion. Early man learned to use this source of potential energy to provide himself with an effective weapon. Materials may also be given potential energy by being twisted, stretched, or compressed.

chapter 25 USING ENERGY THROUGH MACHINES

DURING early times men were limited to a few sources of energy to use in doing their work. Much of the work was done with simple machines operated by men and animals. For example, the largest Egyptian pyramid is made of 2,300,000 stones each weighing about two and one-half tons. Most of these huge stones were obtained from the side of the Nile river opposite the pyramid, ferried across the river, and then pulled up a long inclined plane. The longest inclined plane used was about one third as high as the Empire State Building in New York City. One authority estimated that it must have required the use of 100,000 slaves for twenty years to build this pyramid.

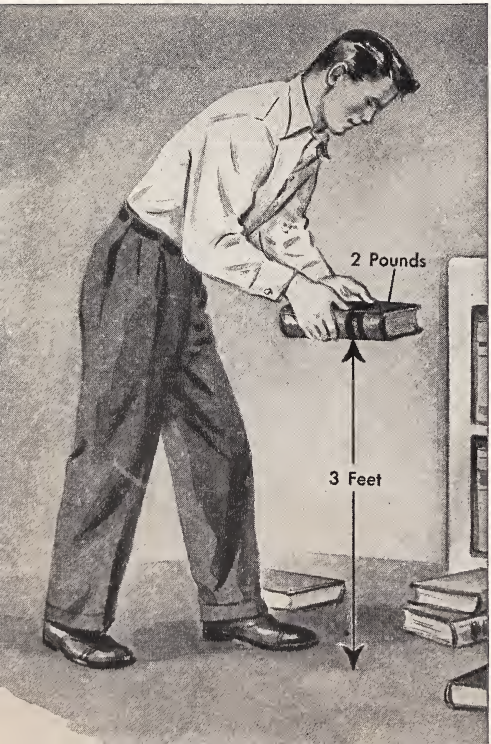
Although we do have new sources of energy, we still do much of our work with the old sources and simple machines used in early days.

PROBLEM 1. What types of energy can be used to do work?

SCIENTIFIC MEANING OF WORK

Have you ever thought about what a person means when he says he has worked hard? If one has been active and feels tired, he may say that he has worked hard, but has he? Many of us use the word *work,* but think little about its exact meaning. To determine how much work is actually done, scientists found that they had to be able to measure it. In order to measure work, they needed to describe it so that it would mean the same to everyone. Scientists agree that work results when a force acts through a distance. Since the amount of the force and the distance through which it acts can be measured accurately, work can also be measured.

Lifting a book from the floor is work because a force is acting through a distance. In this case a force of 2 pounds is required to lift the book, and it is moved a distance of 3 feet from the floor. The boy, therefore, is doing 6 foot-pounds of work (2 pounds × 3 feet).



Measuring work. Let us suppose an object, such as a book, weighing 2 pounds is to be moved from the floor to the top of a table 3 feet above the floor. Since the book weighs 2 pounds, a force of 2 pounds is needed to lift it. The force must act through a distance of 3 feet. Moving the book from the floor to the table top is work because a force is acting through a distance. If the force, in this case 2 pounds, is multiplied by the distance through which it acts, 3 feet, the product is 6. Since pounds are being multiplied by feet, it seemed reasonable to combine the two units, feet and pounds, to get a new unit, *foot-pound,* to be used in measuring work. Thus the work done in moving the book from the floor to the table top is 6 foot-pounds.

Energy. There are two conditions which must be met if work is done according to its scientific definition. First, a force must be used, and second, the force must move through some distance. If either is not present in a situation, work is not being done. For example, suppose someone should push and push upon an overturned automobile until he was completely exhausted without moving the automobile. In the scientific sense, no work was done, because the force exerted by his pushing did not move through any distance. By pushing until he was exhausted, the person had merely used up his capacity to do work. He was so tired that he could no longer push on the automobile. The capacity to do work is called *energy*. It is entirely possible for a person to use up his energy and yet accomplish no work.

Potential energy. In early times men would carry large rocks to the top of the walls surrounding their forts and balance them on the wall. Then if they were attacked, they could drop these rocks on their enemies. The rocks possessed energy because of their position on the top of the wall. The work done in moving the rocks to the top of the wall gave them their energy. Scientists call such energy *potential energy*. The word *potential* really means *stored*. The water behind a dam because of its position has potential energy which is used to generate large amounts of electricity (see Unit 5). Bending, twisting, stretching, and compressing materials also often gives them potential energy that can be used to do work.

Fuels such as oil, wood, coal, and gasoline possess potential energy. When they are burned, they give off heat which can be used to do work. The potential energy of fuels, resulting from their chemical composition, is called *chemical energy*. Another kind of fuel, the food we eat, possesses chemical energy that makes it possible for us to exert force with our muscles and thus to do work.

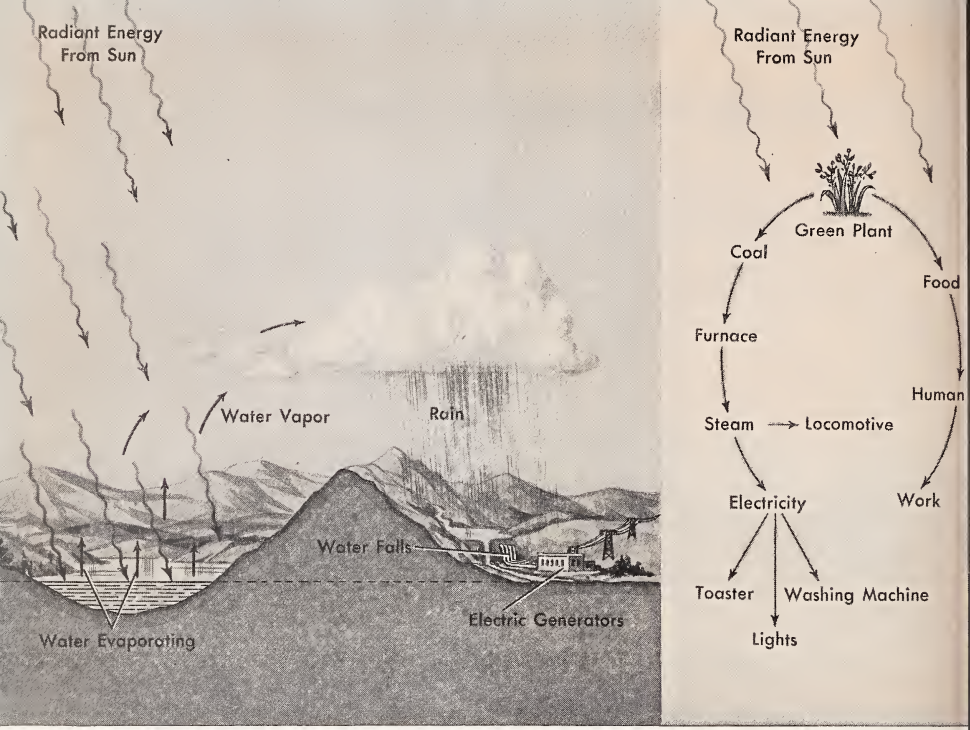
Electricity is another form of potential energy. As you recall from Unit 5, the electric wiring of your home makes this source of potential energy available to you at all times. By merely snapping a switch, you can make it do many kinds of work for you.

In the early morning hours of July 16, 1945, a new type of bomb was exploded in an isolated part of a desert in New Mexico. A new source of potential energy had been tapped. This energy, locked deep within the nucleus of certain kinds of atoms, was called *atomic energy*. Atomic energy is a form of potential energy possessed by all atoms because of their internal structure. Scientists have learned how to use it from the atoms of uranium, thorium, and plutonium.

E. I. du Pont de Nemours & Co.

Scientists have developed this platform to measure the energy a given job requires. This information can be used to find new ways to do the job more efficiently and with less fatigue.

Kinetic energy. In addition to the various types of potential energy all around us, there is another type of energy which scientists call *kinetic energy*. Kinetic energy refers to the ability of an object to do work because



As shown in diagram at left, radiant energy from the sun warms the water in the lake, causing it to evaporate. The water vapor forms clouds and may later fall as rain. The water runs generators to produce electric energy. As shown at right, radiant energy stored by green plants may become mechanical or electric energy.

it is moving. A bullet in flight possesses kinetic energy, because it does work on any object it happens to strike. The kinetic energy of moving automobiles is responsible for the damage when they hit something. The kinetic energy of moving water turns water wheels and water turbines used to do work.

Relationship of potential to kinetic energy. Potential energy must be changed to kinetic energy before it can be used to do work. The rocks raised to the walls of the fort might rest there indefinitely without doing any work. As soon as they are released and start to move toward the earth, they can do their work by hitting some of the enemy. A rifle bullet does no work as long as it remains in the gun. When it is given motion by the force of the exploding powder, it is capable of doing work. The water behind a dam does no work as long as it is held by the dam. When it is allowed to fall swiftly down to the power station, its kinetic energy can be used to do work. Because work is the result of a force acting through a distance, no work is done unless the force moves a distance.

Ancient man lived in a world filled with potential energy. Coal, oil, and water were present in his world, as well as atoms of uranium. These sources of energy were of little value to him because he did not know how to convert them to kinetic energy which could work for him. As we learned how to do that, our modern civilization developed.

Transformation of energy. Energy is often described in terms of the various forms in which it appears. For example, we have already studied several forms of energy, such as radiant energy, heat energy, electric energy, and chemical energy. Energy can be changed from one form to another. The ways by which radiant energy from the sun becomes, through a series of changes, *mechanical energy* and *electric energy* are shown on page 482.

SUMMARY

Since work is the product of a force acting through a distance, the amount of work done depends upon both the size of the force and the distance through which it acts. Work is measured in foot-pounds. Energy, the capacity for doing work, exists in a number of forms. By the transformation of energy from one form to another, man is able to utilize the great sources of potential energy that are in the world all about him.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

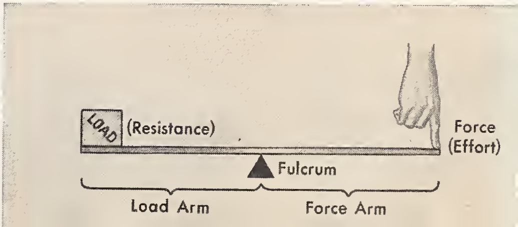
1. The amount of work required to move an object can be determined if one knows (a) the distance the object is moved; (b) the force required to move the object; (c) the speed at which the object moves; (d) the force and the distance through which it moves.
2. A rock balanced on top of a stone wall possesses usable energy in the form of (a) potential energy; (b) kinetic energy; (c) chemical energy; (d) atomic energy.
3. Energy is thought of as the (a) number of molecules a substance contains; (b) speed of a moving object; (c) capacity to do work; (d) weight of an object.
4. An arrow just shot from a bow possesses usable energy in the form of (a) potential energy; (b) kinetic energy; (c) chemical energy; (d) atomic energy.
5. Changing energy from one form to another is known as (a) conservation of energy; (b) transformation of energy; (c) capacity to do work; (d) release of energy.

PROBLEM 2. How are machines used?

SIMPLE MACHINES

A simple machine is a device that enables us to do work more easily than would be possible without it. Everytime we use a knife or fork, sweep the floor with a broom, twist a screwdriver, climb a stairway, turn a door-

Although the fulcrum is not always in the position shown below with respect to the force and load, it is the point about which the lever turns.



knob, and steer an automobile, we use simple machines.

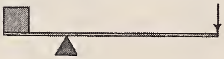
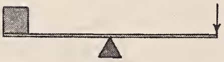
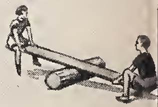
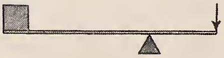
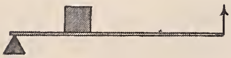
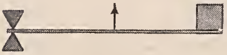
Purposes of simple machines. Some simple machines make it possible to multiply force. Suppose it were necessary to change a flat tire on an automobile. A man cannot exert enough force to lift the automobile so the tire can be changed. With an automobile jack, the force which he exerts on the jack results in a force many times greater being applied to the automobile. For this reason the jack is said to multiply the force that the man exerts upon it. Bottle openers, scissors, pump handles, can openers, nut crackers, pliers, and wrenches are all simple machines that multiply force.

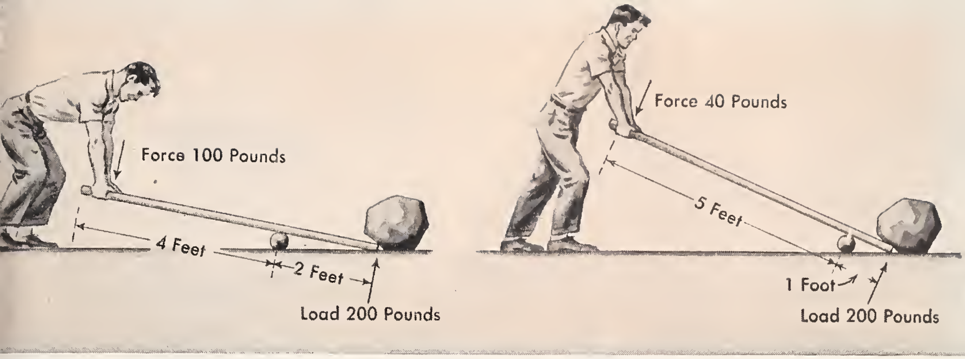
Some simple machines are used to change the direction of a force. For example, the pedal of a bicycle is arranged so that the rider can push downward with his legs and the force he exerts will pull him forward. Construction workers often use pulley wheels so that they can stand on the ground and pull downward to raise a load upward. Changing the direction of a force is often the only reason for using a simple machine.

Some simple machines make it possible to gain speed and distance. When you sweep with a broom, your hands should move slower and through a shorter distance than the bristles of the broom do. When you shovel snow,

Scientists identify three different classes of levers. The way one class differs from another depends upon the position of the fulcrum with respect to the load and the effort. The characteristics of each class together with three uses for I and one use each for II and III are shown.

CLASSES OF LEVERS

CLASS	POSITIONS OF FORCE (↓) LOAD (■) AND FULCRUM (▲)	CHARACTERISTICS	EXAMPLE OF USE
I		1. Changes direction of force 2. Requires less force than load 3. Force moves farther and faster than load	
I		1. Changes direction of force 2. Requires same force as load 3. Force moves same distance and at same rate as load	
I		1. Changes direction of force 2. Requires greater force than load 3. Load moves farther and faster than force	
II		1. Does not change direction of force 2. Requires less force than load 3. Force moves farther and faster than load	
III		1. Does not change direction of force 2. Requires greater force than load 3. Load moves farther and faster than force	



The law of the lever states that whenever the force applied to a lever is multiplied by its distance from the fulcrum, the result is always the same as when the load is multiplied by its distance from the fulcrum.

the load on the shovel should travel faster and through a greater distance than your hands do. Fishing poles, golf clubs, and baseball bats also make a gain of speed and distance possible.

The lever. A scientist in ancient times is reported to have once said, "Give me a lever long enough and a place upon which to support it, and I could lift the world!" Of course such a feat is impossible, but without levers, our modern civilization could not exist.

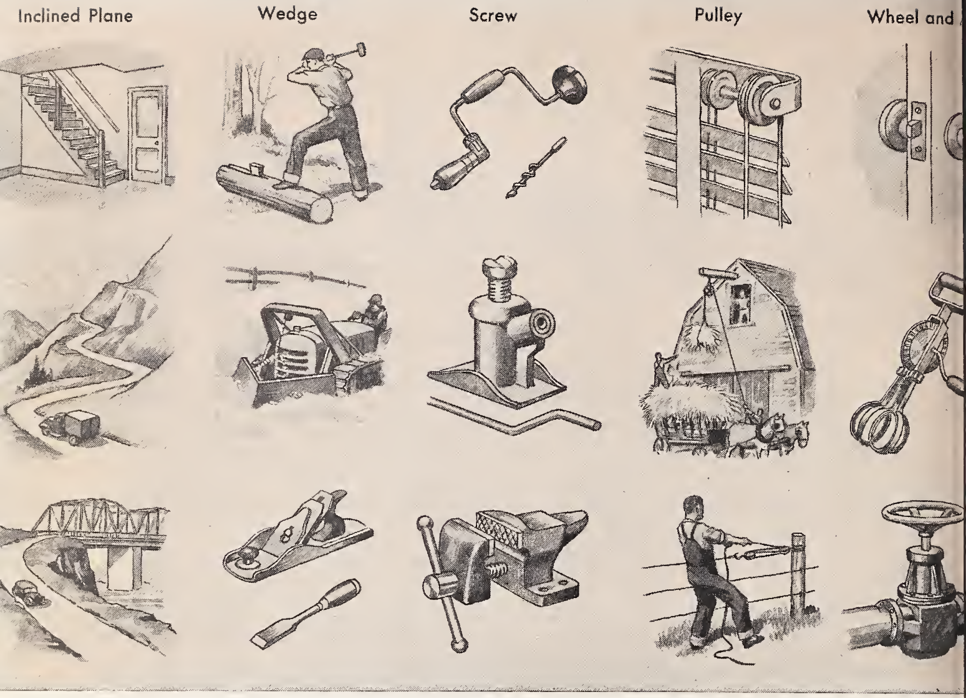
We all use levers every day. Our fingers, arms, and legs are levers. By using them we can move about, pick up objects, and apply force in many ways. Other levers that we frequently use are knives, forks, shovels, rakes, brooms, and golf clubs.

A study of levers will help us understand how we can use them more effectively. In the drawing on page 483 notice that the point about which the lever turns is called the *fulcrum*. At one end of the lever you will see a *load* (resistance), while at the other end of the lever a *force* (effort) is being applied. The parts of the bar serving as the lever are called *arms*. The classes of levers, their characteristics and an example of their use is shown on page 484.

The lever at work. A great many experiments with levers have shown that whenever the force applied to a lever is multiplied by its distance from the fulcrum, the result is always the same as that obtained when the load is multiplied by its distance from the fulcrum. This is true only if the weight of the lever and the friction between the lever and its support are not considered. This statement is called *the law of the lever*. The application of the law of the lever to the problem of moving a stone is shown above.

The inclined plane. When men load and unload heavy objects from a truck, they often use another simple machine. It is merely a long plank or platform extending from the bottom of the truck to the ground, up or down which the load travels. This simple machine is called an *inclined plane*. Like the lever, it multiplies the force which a man can exert. Inclined planes were among the first simple machines used by man, and are still used in a great variety of ways, some of which are shown above.

The wedge. The blade of an axe or hatchet is constructed so that both sides slope away from the cutting edge, thus forming a V. A line from the point through the middle of the V



Examples of five different types of simple machines commonly used in doing work.

shows that the axe is really two inclined planes. Some of the common uses of wedges are shown above.

The screw. A common wood screw is an example of one of the most widely used simple machines. The threads are arranged as an inclined plane which winds around the screw. Propellers on airplanes and ships are built so that when they turn they act as screws. For some uses of screws, see above.

The pulley. It is often necessary to lift large loads where neither a lever nor an inclined plane can be used. In such cases pulleys can often be used. A pulley wheel can be thought of as a number of levers that are constantly turning about the center of the pulley wheel as it operates. Careful study of the drawing on page 487 will show that fixed pulley wheels operate as first-class levers, while movable pulley wheels operate as second-class levers. When several pulley wheels, both fixed and movable, are combined into a single system, they are known as a *block and tackle,* a device that makes it possible to multiply the force applied to it a great many times.

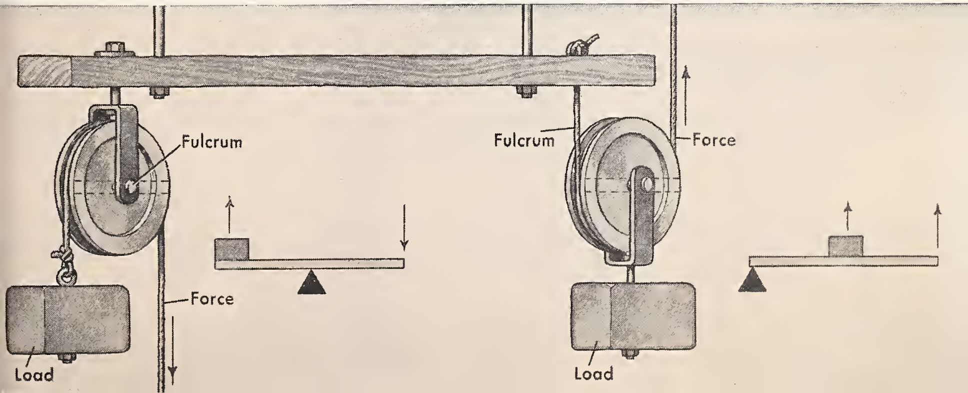
Wheel and axle. The steering wheel on an automobile is an example of another type of simple machine, called a *wheel and axle*. The effort is applied to the rim of the wheel. The load is the resistance to be overcome in moving the front wheels of the automobile. The axle connected to the steering wheel moves the load and turns the front wheels.

The wheel and axle multiplies force in much the same manner as the other simple machines. The force applied to the rim of the wheel travels a much greater distance in one turn of the wheel than the load moves in one turn of the axle. By applying the law of the lever (see page 485) in this manner, it is possible to move a large load with a smaller force. Some of the uses of a wheel and axle are shown on page 486.

Hydraulic machines. Machines which use liquids to exert force are called *hydraulic machines*. They are used for pressing cotton in bales, punching holes in steel, and lifting heavy weights, especially where a large force is needed. The way liquids can be made to exert such great force in these machines can be demonstrated very simply. If a thin-walled glass bottle is completely filled with water and a cork is then forced into it, the bottle will break. This happens because a force applied at one place on an enclosed liquid is conducted through the liquid without loss. For example, if the area of the bottom of the cork is one square inch and if the cork is pushed into the bottle with a force of 15 pounds, the 15-pound force is sent from the bottom of the cork through the water to all parts of the bottle. This means that the water pushes against the walls of the bottle with a force of 15 pounds on every square inch. If the surface of the inside of the bottle is 50 square inches, the water pushes against the inside of the bottle with a total force of 750 pounds, enough to break the bottle.

A force travels throughout an enclosed liquid, such as water in the bottle, because a liquid can be compressed only slightly. The molecules of a liquid are so close together that an additional force, unless it is exceedingly great, cannot compress the liquid into a smaller space. The liquid therefore transmits the force, and it is this force that is used in operating hydraulic machines. How hydraulic machines operate is shown on page 488.

Hydraulic automobile brakes operate as shown on page 524. When the brake pedal is pushed down, a force is applied to a liquid in a small cylinder. This force is carried by the liquid throughout the braking system and is applied to a piston in another cylinder at each wheel. The piston at the wheel cylinder applies the brake. Hydraulic brakes are used on most automobiles because they make it possible to get the same braking force at each wheel.



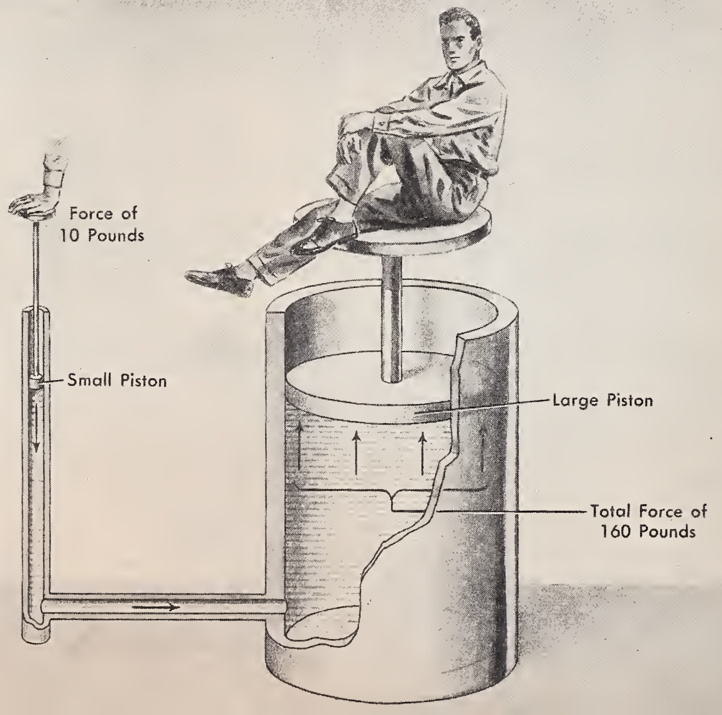
The fixed pulley (left) acts as a first-class lever similar to the one diagramed near it. Since the fulcrum is at the center, it changes only the direction of a force. The movable pulley (right) acts as a second-class lever diagramed near it and has the characteristics of such a lever.

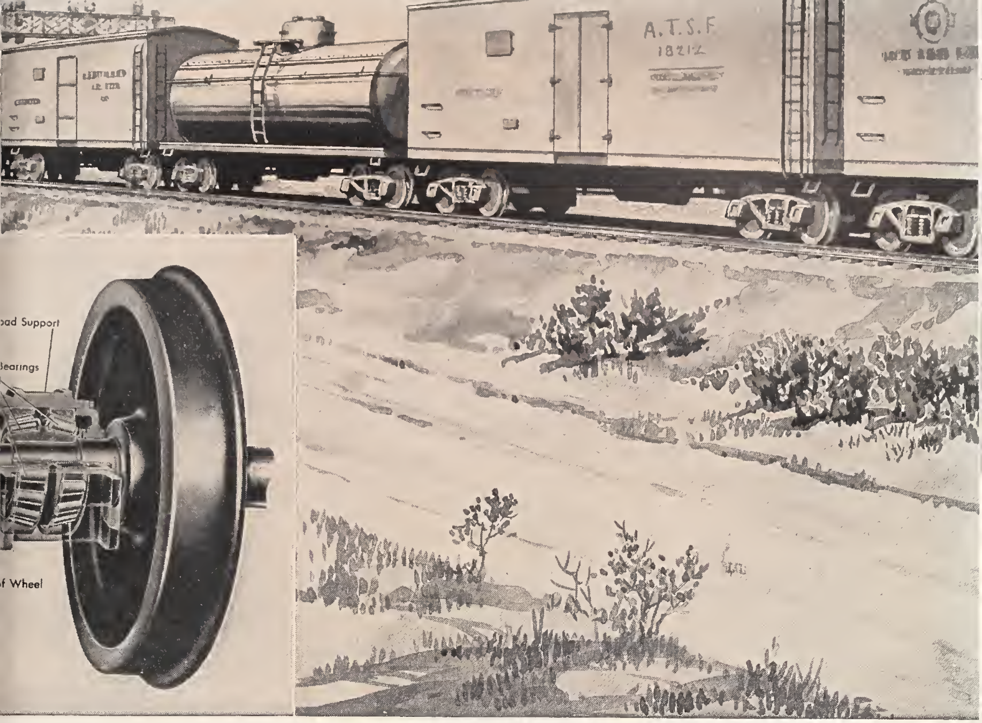
Hydraulic machines are used for many purposes. Barber and dentist chairs, for example, are supported on the large piston of a hydraulic machine. To raise the chair, the operator applies a force to a small piston by pumping a lever. Automobile lifts at service stations, elevators in some buildings, and the devices for raising and lowering the landing gear on airplanes are hydraulic machines. Hydraulic machines are also in the power-steering systems used in automobiles. Although water can be used as the liquid in hydraulic machines, under most conditions some other liquids such as mixtures of oils must be used.

OPERATING SIMPLE MACHINES

Mechanical advantage. One measure for determining the advantage gained by using simple machines is called *mechanical advantage*. The mechanical advantage is simply a number expressing relationship between the force obtained from the machine and the force put into the machine. In all simple machines the actual mechanical advantage can be obtained by dividing the amount of the load moved with the machine by the amount of the force required to operate the machine. For example, if a load of 600 pounds is moved by a force of 100 pounds with a lever, the mechanical advantage of the lever is

The operation of a hydraulic machine. The force of 10 pounds exerted by small piston (area 1 square inch) is transmitted through the fluid to each square inch of the large piston (160 square inches). The total force is $16 \times 10 = 160$ pounds. The small piston must move 16 inches to move the 160-pound man on the large piston one inch, so although the machine multiplies force, it does not save work.





Timken Roller Bearing Company

When railway cars are equipped with roller bearings such as shown above, they can be moved more easily because the bearing reduces the friction on the axle. Less power is therefore required to pull the cars.

600 divided by 100, or 6. In a similar manner, the mechanical advantage for any of the simple machines can be determined.

Efficiency of machines. It might be thought that the use of simple machines would save work, but this is not true. It is true that the loads moved by the machines are often much greater than the amount of force required to operate the machine. In such cases the applied force always moves through a much greater distance than the load does. Thus, no work is saved. In fact, when the effects of the friction in a simple machine are considered, it is found that more work is put into the machine than is obtained from it.

Scientists express the relationship between the work obtained from a machine and the work put into it as its *efficiency*. Efficiency is given as a percentage. If 90 per cent as much work is obtained from a machine as is put into it, the machine is said to have an efficiency of 90 per cent. No machines are 100 per cent efficient because some friction must be overcome as every machine is used. Although simple machines do not save work, they are extremely valuable because with them it is possible to perform easily many activities that could be done only with difficulty, or not at all, without them.

In order to make machines as efficient as possible, it is necessary to control the friction associated with their use. If friction generates a large amount of heat which may damage the machine, or uses up too much of the force put into the machine, it must be reduced.

Reducing friction. More force is required to slide a wooden block over a rough surface than to slide the same block over a smooth surface. This simple fact illustrates one way to reduce friction: make the sliding surfaces as smooth as possible. Many of the moving parts of machines are highly polished to help reduce friction.

Ancient man learned that it was easier to roll a load over logs than to slide it along. The reason for this is that the friction of rolling is usually much less than the friction of sliding. It is thought that from the early use of logs to reduce friction, a wheel was finally developed. The development of the wheel was one of the most significant steps in man's history. By substituting rolling friction for sliding friction, the wheel made it possible to move larger loads at higher rates of speed. Ball bearings and roller bearings like those shown on page 489 are also widely used to reduce friction in the same way. Civilization today could not get along without these devices to reduce friction.

Specially designed treads, such as the one shown below, are built on tires for use in winter driving. Such treads increase friction between the tire and snow, making driving safer.

Goodyear Tire and Rubber Company

A third way to reduce friction is by *lubrication*. Lubrication can be accomplished by placing some material such as oil or grease between the two moving surfaces. Modern high-speed machinery would soon destroy itself because of the heat from friction if the moving parts were not always lubricated.

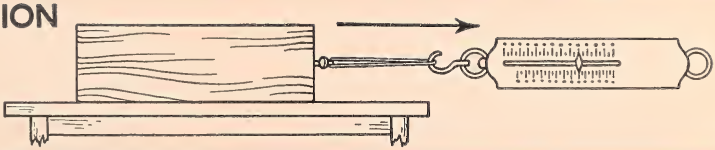
Increasing friction. To use the force developed by a machine effectively, it is sometimes necessary to increase the friction between some part of the machine and the object to which the force is being applied. The brake linings on an automobile help stop the automobile because of the friction they create on drums attached to the wheels. Care must be taken to see that grease does not get on the brake linings, for it would reduce the friction and thus make the brakes much less effective in stopping the automobile. Icy, snowy, wet, or muddy highways reduce the friction between the wheels of a vehicle and the highway to such an extent that often transportation is impossible. Chains are placed on the wheels to increase the friction and thereby get enough hold to enable vehicles to proceed. Train engineers sometimes need to use sand between the engine wheels and the track so that there is enough friction to enable the engine to pull the heavy train.

Complex machines. Although simple machines are widely used, much of the work of the world is done by incredibly complex machines. Careful study will show that complex machines are combinations of a great many simple machines. A high-speed printing press is such a machine. The blank paper travels through one such press at a speed of 20 miles per hour. While going through the press, the pages are printed, the paper is cut, folded, and delivered completely printed at the rate of 30,000 thirty-two page papers per hour. Each of the many simple machines which make up such a giant printing press does some little part in the total operation. All together they perform a task almost beyond imagination.

SUMMARY

Simple machines add to the convenience with which work can be done by multiplying force, changing the direction of a force, and increasing speed and distance through which a force acts. However, simple machines do not save work. The mechanical advantage and efficiency of simple machines can be accurately measured. The efficiency of machines can be increased by polishing surfaces, by substituting rolling for sliding friction, and by lubrication. Complex machines are combinations of simple machines.

OBSERVATION



What to observe. Some methods of reducing friction.

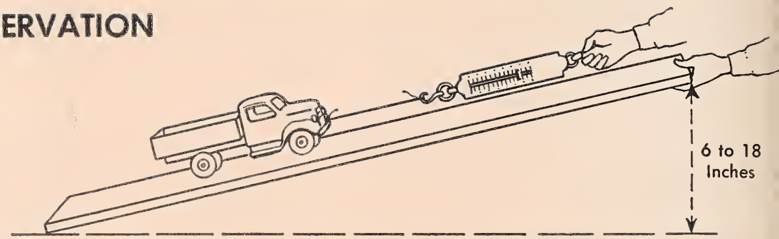
How to observe them. 1. Obtain a block of wood 2 inches by 4 inches and about 6 inches long. Drive a small nail part way into the center of one end of the block, and bend the nail over so that it can be used as a hook. Hook a spring scale onto the block and pull it at a steady speed across sheets of sandpaper of varying degrees of roughness. Also pull it across a smooth table top. Note the reading on the scale in each instance.

2. Support the block on two round pencils placed about 2 inches apart underneath the front end. Pull the block over the pencils and note the reading on the scale.

3. Compare the amount of force it takes to pull the block along the smooth, dry table top with that necessary to pull it along the same table top covered with a film of light oil.

Interpretation of your observation. Write one sentence stating three ways of reducing friction between two moving surfaces.

OBSERVATION

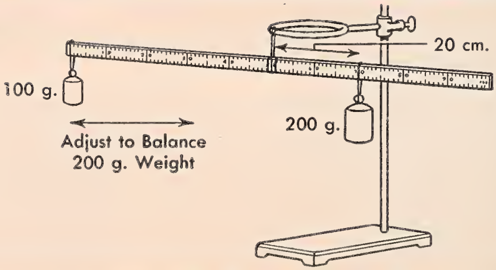


What to observe. The effect of an inclined plane on the force required to lift a load.

How to observe it. Obtain a toy truck or automobile about a foot long, and measure with a spring scale the amount of force required to lift it vertically. Now measure the amount of force required to pull the automobile up a 4-foot board raised first 6 inches, then 12 inches, and finally 18 inches at one end.

Interpretation of your observation. Write one sentence stating how a 4-foot inclined plane affects the force required to lift an object 6, 12, and 18 inches when compared with the force required to lift the same weight vertically.

DEMONSTRATION



Generalization to be demonstrated. The force applied to a lever multiplied by its distance from the fulcrum equals the weight lifted by the lever multiplied by its distance from the fulcrum.

What you need. Meter stick; adjustable clamp to support meter stick; ringstand; two weights (100 grams and 200 grams); string.

What to do. Attach the clamp to the center of the meter stick, and suspend it with a string from the ringstand so that the meter stick hangs parallel to the table top. (If a clamp is not available, the meter

Weight (1)	Distance to center (cm) (2)	Column 1 times Column 2 (3)	Weight (4)	Distance to center (cm) (5)	Column 4 times Column 5 (6)

stick can be supported with the string alone.) Tie one end of a piece of string to a 100-gram weight, and form a loop with the other end so that it will slip over the meter stick. In a similar manner, fasten another piece of string to a 200-gram weight. Hang the 200-gram weight on the meter stick about 20 centimeters to the right of the central point where it is suspended. Now hang the 100-gram weight at a position to the left of the center where it exactly balances the 200-gram weight on the right side. When this position is found, see how far it is from the center. Place the 200-gram weight in three or four other positions and again balance it with the 100-gram weight. Record your observations in a table like the one above.

What to observe. How does the product recorded in Column 3 compare with that recorded in Column 6 in each case?

What does it mean? Do the results you obtained tend to prove or disprove the generalization stated at the beginning?

A basic assumption in this demonstration. The measurements obtained in this demonstration are similar to those that would be obtained from any kind of lever.

TEST YOURSELF

In the proper place on your answer sheet write the letter of the ending which best completes each statement.

1. Simple machines cannot be used to (a) multiply force; (b) change the direction of a force; (c) save work; (d) gain speed and distance.
2. When a lever has the force applied between the fulcrum and the load, the lever is (a) a first-class lever; (b) a second-class lever; (c) a third-class lever; (d) a fourth-class lever.
3. If a simple machine moves a load of 1,000 pounds with a force of 250 pounds, the mechanical advantage of the machine is (a) 0.25; (b) 4; (c) 250; (d) 1,000.
4. The relationship between the work obtained from a simple machine and the work put into the machine is known as (a) efficiency; (b) mechanical advantage; (c) work; (d) energy.
5. Lubrication makes it possible for some machines to operate more

efficiently by (a) reducing the load; (b) increasing the friction; (c) reducing the friction; (d) decreasing the distance.

CHAPTER ACTIVITIES

REVIEW YOUR UNDERSTANDING

1. You have learned that there are six types of simple machines. They are:

1. lever
2. wheel and axle
3. pulley
4. inclined plane
5. wedge
6. screw

Listed here are a number of common devices, each made up of one or more types of simple machines. Decide which type of simple machine each device is, and write the number of that simple machine beside the letter of the device in the proper place on your answer sheet. If a device is made up of two or more simple machines, write the numbers for each machine in the device. **Do not write in your textbook.**

a. Knife blade
b. Reel on a fishing pole
c. Wheelbarrow
d. Bolt
e. Crowbar
f. Automobile steering wheel
g. Gangplank for ships
h. Spiral stairway
i. Block and tackle
j. Oars
k. Nutcracker
l. Seesaw
m. Scissors
n. Ramp
o. Tweezers

SOLVE MATHEMATICAL PROBLEMS

1. How many foot-pounds of work is done when a piano weighing 750 pounds is lifted 3 feet into a truck?

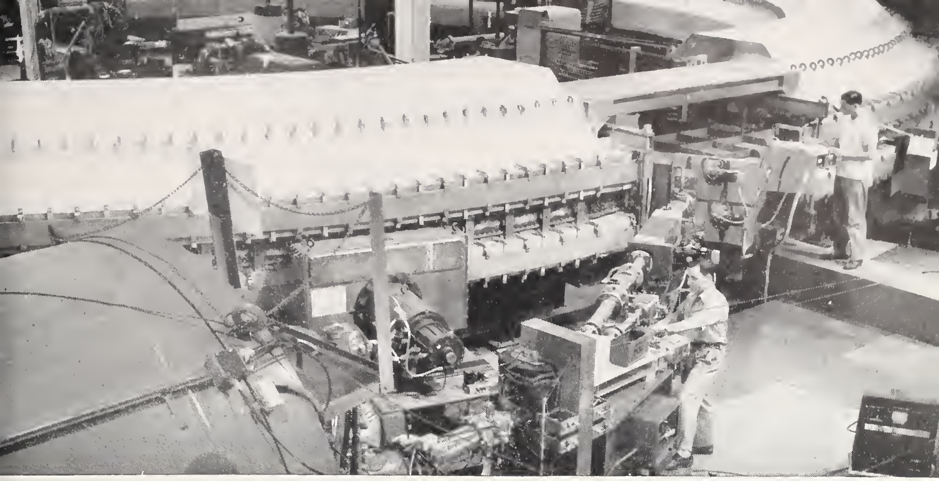
2. When a 9-foot ramp was used to load the same piano onto the truck, it was found that a force of 275 pounds was needed to roll the piano up the ramp. How much work was done in rolling the piano up?

3. What was the efficiency of the ramp used in Problem 2?

4. A 12-foot bar is used as a lever with the fulcrum placed 2 feet from one end. If a force of 200 pounds were applied to the end of the lever that is 10 feet from the fulcrum, what load could be lifted by the lever? (Neglect friction and the weight of the bar.)

5. It was found that with a system of pulleys used to lift a load, the force had to move 10 feet while the load moved 6 inches. What is the mechanical advantage of the pulley system?

6. Neglecting friction, how much force would be required to lift a 1000-pound load with the pulley system described in Problem 5?



Brookhaven National Laboratory

The huge cosmotron speeds up particles used in bombarding atoms. Scientists study the resulting fragments to gain clues to the structure of the nuclei of atoms.

chapter 26 FORCE FROM ENERGY

ALTHOUGH man still uses simple machines, he has learned how to build complex machines that will do more work than simple machines. To operate these machines requires more force than can be obtained conveniently from man or animals, so engines were built to use energy rapidly and to develop the large forces needed for transportation and for industry, agriculture, and our many other activities.

Engines also make it possible to do a large amount of work in a short period of time. A trainload of merchandise could be transported from Chicago to Omaha with horses and wagons or even by men on foot if time were not important; but since it is important, we use vehicles operated by engines capable of doing large amounts of work rapidly. How is time related to work done? How do engines develop force from energy? How was a new source of energy, atomic energy, discovered, and how has it been used?

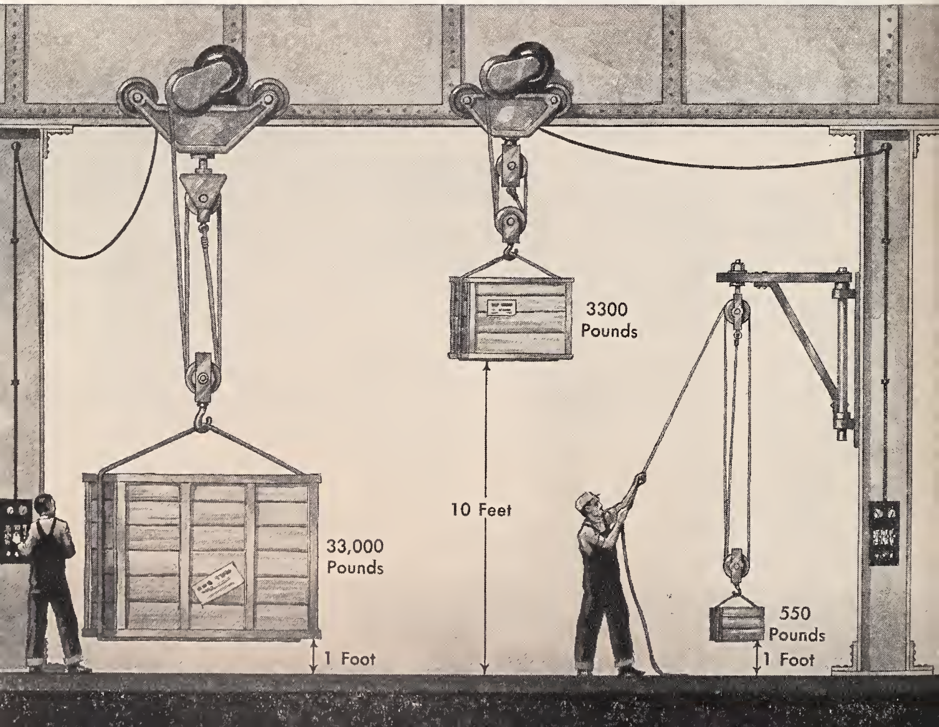
PROBLEM 1. How do engines develop force?

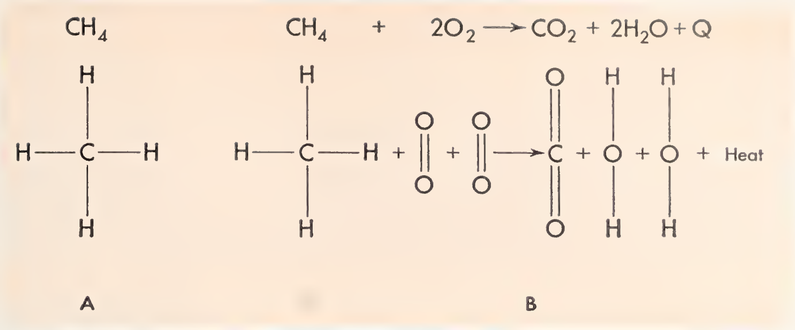
WORK AND POWER

Distinction between work and power. Which is easier to do, walk up steps or run up them? Of course it is more difficult to run up a stairway than to climb it slowly. Yet the amount of work done in each case is exactly the same. For example, suppose a man weighing 200 pounds walked up a 15-foot stairway. He would have done 3,000 (200 pounds × 15 feet) foot-pounds of work. Now suppose he should run up the same stairway in one half the time it took him to walk up it. He would still be doing only 3,000 foot-pounds of work, but he would be doing it in one half the time. The difference between walking and running up the stairway is in time, not in work. Scientists use the term *power* to describe the rate at which work is done. The 200-pound man had to produce twice as much power to run up the stairs as to walk up the stairs. It is the extra power that is required that makes it more difficult to do work rapidly.

Measuring power. An early Scottish scientist, James Watt, is credited with establishing one of the basic units for measuring power. Seeing a need for some unit with which to measure

The power required to lift 33,000 pounds a distance of 1 foot in 1 minute is 1 horsepower. To lift a load of 3300 pounds a distance of 10 feet in 1 minute would also require 1 horsepower. If the 550-pound load were lifted 1 foot in 1 second, it would require 1 horsepower.





A (left) represents a molecule of methane made up of one atom of carbon and four atoms of hydrogen. The lines represent forces holding the atoms together in the molecule. In B (right) is shown what happens when a molecule of methane is oxidized. When one molecule of the methane is combined with two molecules of oxygen, one molecule of carbon dioxide and two water molecules result, with energy given off as heat.

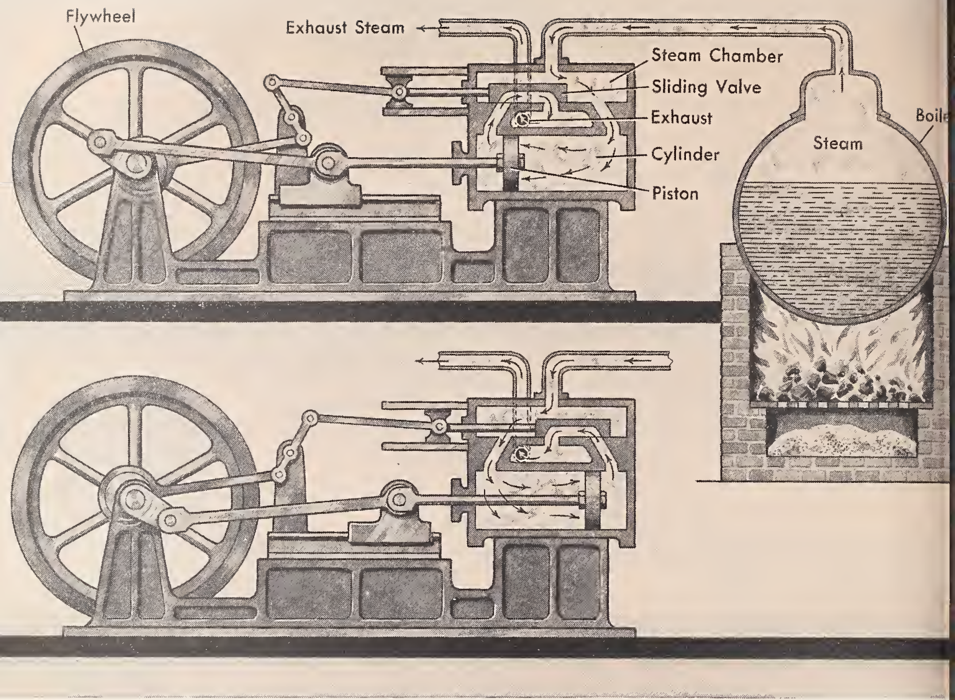
power, he is said to have carried on experiments to determine how much work a good horse could do. Estimating that the best horses could do 33,000 foot-pounds of work per minute, he established 33,000 foot-pounds per minute as one *horsepower*. This value has never been changed.

You will remember from studying Unit 5 that the rate at which electricity is used is measured in watts rather than in horsepower. However, watts can be converted easily into horsepower. Experiments have shown that 746 watts are equal to one horsepower. An electric motor using 1,492 watts of electricity is a two-horsepower motor.

Force from energy. When men use simple machines, they usually operate them from the force of their muscles. The kinetic energy of running water develops the force needed to produce electricity in the large hydroelectric power plants. The force produced by an automobile engine which drives the automobile is developed from the chemical energy of the fuel the engine uses. Steam-railroad locomotives develop the force for pulling the train from the kinetic energy of the molecules of steam, which in turn receive their energy from the chemical energy in the coal burned in the locomotive.

Engines, sometimes called motors, are the devices used to develop force from energy. There are gasoline engines, steam engines, and jet engines; electric motors, automobile motors, and airplane motors. The primary purpose of engines is to develop the force to do work from some type of energy.

Releasing potential energy of fuels. Common fuels such as gasoline, oil, and gas consist of large molecules containing many atoms of carbon and hydrogen. Chemists imagine one such molecule, known as *methane*, to have the structure shown in A above. The burning of a molecule of methane



In a steam engine, the flow of steam to the cylinder, which contains a tight-fitting piston, is controlled by a sliding valve. Steam entering the cylinder pushes the piston forward (top). Then the valve slides and steam pushes the piston back (bottom). Steam entering first one end of the cylinder and then the other moves the piston back and forth.

gas as pictured by a chemist is shown in Part B. Less energy is needed to hold the molecules of carbon dioxide and water together than to hold the molecule of methane together. Some of the extra energy is released in the form of heat. In a similar manner, heat is obtained when ordinary fuels are burned.

Source of potential energy of fuels. In Unit 9 we learned that green plants can form sugar from carbon dioxide and water with the aid of sunlight. The green plant in manufacturing sugar rearranges the simpler compounds to form a more complex one which requires a greater amount of energy to bind its atoms together. The sunlight furnishes the extra energy needed. The plant changes the sugar molecules into other plant materials such as wood which may be used as fuel. As you remember, the fuels methane gas, petroleum, and coal were formed from plant materials which have been buried in the earth for ages. Bound up in each molecule of these fuels is a small amount of the sun's energy which we release when we burn them. Thus the sun is the ultimate source of the energy of our common fuels.

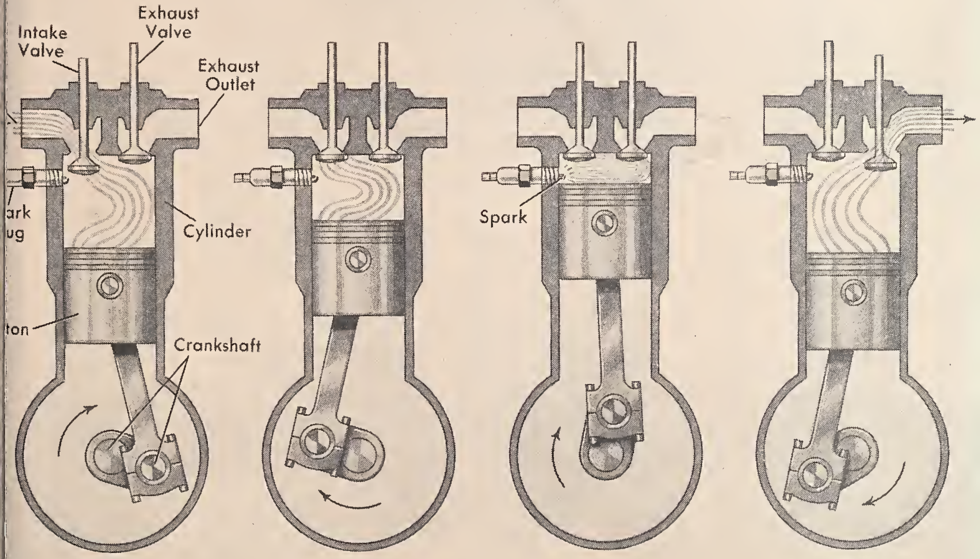
KINDS OF ENGINES

Force from steam engines. In Unit 6 we learned that molecules of steam are in extremely rapid motion. Billions of tiny molecules moving rapidly possess a considerable amount of kinetic energy which can be converted by a steam engine into a force that can be used to operate machinery. One type of steam engine is shown on page 498. In such an engine, the back-and-forth motion of the piston cannot be used to drive machinery until it is changed to a turning, or *rotary,* motion. The change from back-and-forth motion to a rotary motion is accomplished by the *crankshaft,* a form of wheel and axle with most of the wheel left out. The force of the piston is applied to the rim of the wheel by a rod connecting the piston to the crankshaft. The piston, moving back and forth, turns the wheel, and the force to operate the machinery is supplied by the axle. Steam engines are used in railroad locomotives, in many stationary power plants for producing electricity, and in operating machines in factories.

The steam turbine is another type of steam engine. As shown on page 532, the steam turbine is simply a wheel and axle; the steam causes the wheel to turn, and the axle drives the machinery. Steam turbines are used in some large ships, electric generators, and some railroad locomotives.

External- and internal-combustion engines. In all steam engines, the fuel is burned outside the engine. Heat from the burning fuel changes water to steam which operates the engine.

In a four-stroke cycle engine a mixture of gaseous fuel and air enters the cylinder during the intake stroke. It is highly compressed during the compression stroke. A spark ignites the fuel and the heat expands the gases, driving the piston down to form the power stroke. Finally, the burned gases are forced out in the exhaust stroke and the cylinder repeats the cycle.



Intake Stroke

Compression Stroke

Power Stroke

Exhaust Stroke

Such engines are called *external-combustion engines.* In many engines the fuel is burned in the cylinder of the engine, rather than in an outside firebox, and these are called *internal-combustion engines.* They are commonly used in automobiles, airplanes, trucks, and buses.

Gasoline engines. The operation of a gasoline engine, as well as any other type of internal-combustion engine, depends upon the fact that, when a small amount of fuel is mixed with a larger amount of air, a substance is produced that will burn very rapidly. In the gasoline engine, the fuel is mixed with air in a device called a *carburetor,* and the mixture is then burned rapidly in the cylinders. As it burns, a large amount of heat is produced, causing the remaining gases to expand. The expanding gases produce the force which drives a piston back and forth in the cylinder. The movement of the piston then makes it possible for the engine to run machinery and do work.

Although gasoline engines often have more than one cylinder, each cylinder operates in the manner shown on page 499. Since it requires four strokes of a piston to complete the cycle of operation, this type of engine is called a *four-stroke cycle* engine. A great many gasoline engines, including those in most automobiles, trucks, and tractors, are four-stroke cycle engines. However, some smaller engines, such as those used in outboard motors and motor bicycles, are two-stroke cycle engines.

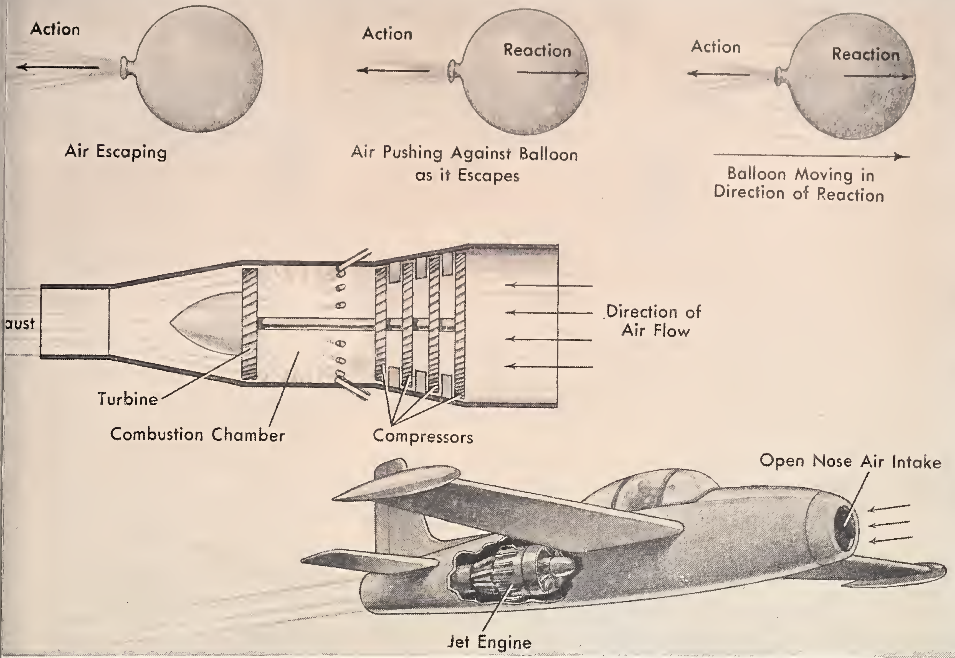
Diesel engines. In a gasoline engine, an electric spark ignites the fuel in the cylinder. In the Diesel engine, however, fuel is sprayed into the cylinder and compressed so highly that the heat from the compression (see Unit 6) causes the fuel to explode. In these engines, neither a carburetor nor an electrical system is required. Otherwise the Diesel engine is quite similar to a gasoline engine. Diesel engines can be operated on a low-grade fuel that is much cheaper than gasoline.

Diesel engines are often used in large stationary power plants, in some buses and large trucks, and some ships and railroad locomotives.

Jet engines. When you release the air from a small rubber balloon, the balloon will dart rapidly through the air. It has become a simple jet engine. A rotating lawn sprinkler is also a jet engine. The force exerted by a jet engine is developed within the engine itself. It does not come from the gases pushing against the air as they leave the jet. Where, then, does it come from?

It was discovered many years ago that for every action, there is an equal and opposite reaction. There are many common examples of this fact. If you jump from a rowboat to the shore, the boat will be forced in a direction opposite from that in which you jumped. When a gun is fired, the bullet and the hot gases leaving it force it backward as they leave the gun barrel. The drawing on page 501 will help explain how the force is developed in a jet engine. In such an engine, the gases must push against something in order for them to issue at high speed from the jet. They push against the engine itself, thus giving the entire engine a forward push equal to the push of the gases as they leave the jets.

Force from jets is usually obtained from two types of engines. In one type, commonly referred to as a *turbojet en-*



As the air escapes from the balloon above, there is an action in the direction in which the air is escaping, as well as a reaction in the opposite direction which pushes the balloon forward. Similarly, air is scooped into the front of the turbojet engine shown in the center, compressed, and used to burn fuel in the combustion chamber. The gases formed by combustion are forced out of the exhaust, causing a reaction against the engine which pushes it forward at high speeds.

gine, air is scooped in the front of the engine and used to burn fuel; the resulting gases are forced out of the jet at high speed. This type of engine is used in airplanes (see page 537). Since it depends upon air for burning the fuel, a plane with such a jet engine cannot fly beyond the atmosphere. The other type of engine depending upon jets for power is known as a *rocket* engine. Since the fuel used in rockets does not need outside air to make it burn, the rocket engine could develop power even though there is no atmosphere, as in the space between planets.

Jets and rockets are most often rated in terms of the force they develop to drive the plane forward. This force is known as *thrust* and is measured in pounds. The engine shown on page 537 develops enormous thrust.

SUMMARY

Scientists use the term power to describe the rate at which work is being done. It is measured in units called horsepower. External- and internal-combustion engines are used to obtain force from our sources of potential energy. These engines are rapidly replacing human beings in doing the work of our modern civilization.

OBSERVATION

What to observe. The effect upon your body of developing power at different rates.

How to observe it. 1. Count your pulse rate by the method described on page 357. Walk slowly up a flight of steps while someone times you accurately with a stop watch. Count your pulse rate after climbing the stairs. Find the height of one step and multiply it by the number of steps to find out how high you lifted yourself. The total height in feet multiplied by your weight in pounds will give you the amount of work you did. Find the work you did in one second by dividing the total work you did by the number of seconds it took you to do it. The work you did in one second divided by 550 will give you the horsepower you developed as you walked up the stairs. Compare your power output to the increase in pulse rate.

2. Repeat part 1, running rather than walking up the stairs. Again compare power output with increase in pulse rate.

Interpretation of your observation. Write one sentence stating the relation between power output and your pulse rate.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The factor used in measuring power which is *not* used in measuring work is (a) weight; (b) distance; (c) force; (d) time.
2. The energy which plants need to build complex molecules from simpler ones is obtained from (a) water; (b) food; (c) sunlight; (d) minerals.
3. The force used to drive the piston of a steam engine back and forth is obtained from (a) water put into the boiler; (b) the molecules of the metal of which the engine is made; (c) the kinetic energy of the molecules of steam; (d) the kinetic energy of air molecules.
4. The stroke of a four-stroke cycle engine which develops the force used to drive machines is called (a) the power stroke; (b) the intake stroke; (c) the exhaust stroke; and (d) the compression stroke.
5. An engine built to operate on a

force developed in the same manner as that which causes a gun to recoil when fired is known as a (a) steam engine; (b) Diesel engine; (c) four-stroke cycle gas engine; (d) jet engine.

PROBLEM 2. How may atomic energy be used?

THE DAWN OF THE ATOMIC AGE

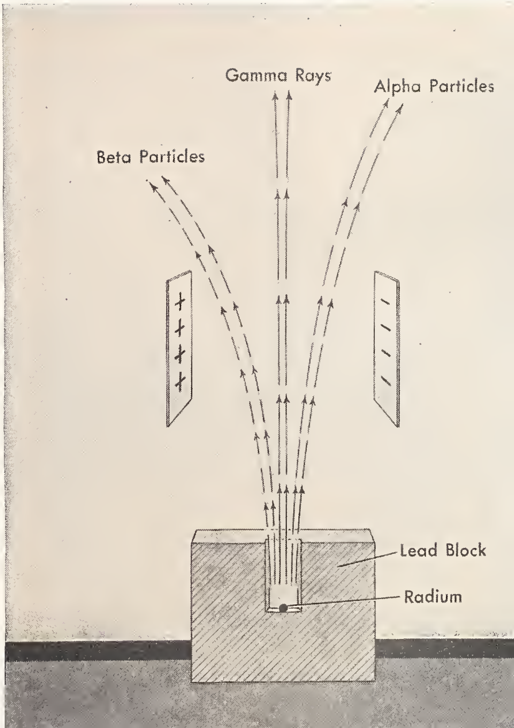
Einstein's work. Just after the turn of the twentieth century, newspaper writers were publishing unusual stories about the tremendous amounts of energy locked within the atoms. If it could be used in some way, there would be enough in a cup of water to drive a large ocean liner across the Atlantic Ocean and back. Or, again, the fuel to run an automobile for a lifetime could be carried in a container the size of a fountain pen. These statements were based on a theory stated by Albert Einstein in 1905. He believed that all the matter of the universe was somewhat like condensed energy and that all energy was somewhat like diluted matter. In other words, matter and energy were essentially the same thing in different forms.

If this hypothesis were true, then deep within the atom there must be a tremendous amount of energy which could be obtained only by converting some of the matter of the atom into energy. Calculations based upon Einstein's theory revealed that if 2.2 pounds of matter could be changed into energy, it would produce 25 billion kilowatt hours of electricity, as compared to 8.5 kilowatt hours from burning an equal amount of coal. It is this potential energy locked in the atoms that we call atomic energy to distinguish it from the energy of the molecules of fuel called chemical energy (see page 481).

DEVELOPMENT OF ATOMIC ENERGY

Radium. In 1896 Henri Becquerel, a French scientist, accidentally discov-

The diagram shows how an electric field affects the rays from radium. Alpha (helium nuclei) travel up to 12,000 miles per second, Beta from 80,000 to 180,000 miles per second, and Gamma at the speed of light.



ered that a piece of uranium ore would darken a photographic plate when placed near it. Further investigation revealed that a type of uranium ore called *pitchblende* was especially powerful in its ability to affect photographic plates. Not having time to pursue the problem further, he turned it over to Pierre Curie and his Polish wife, Marie Curie. After a tremendous amount of work, the Curies finally obtained about half a teaspoonful of a very powerful substance from about eight tons of uranium ore. They named this new material *radium*.

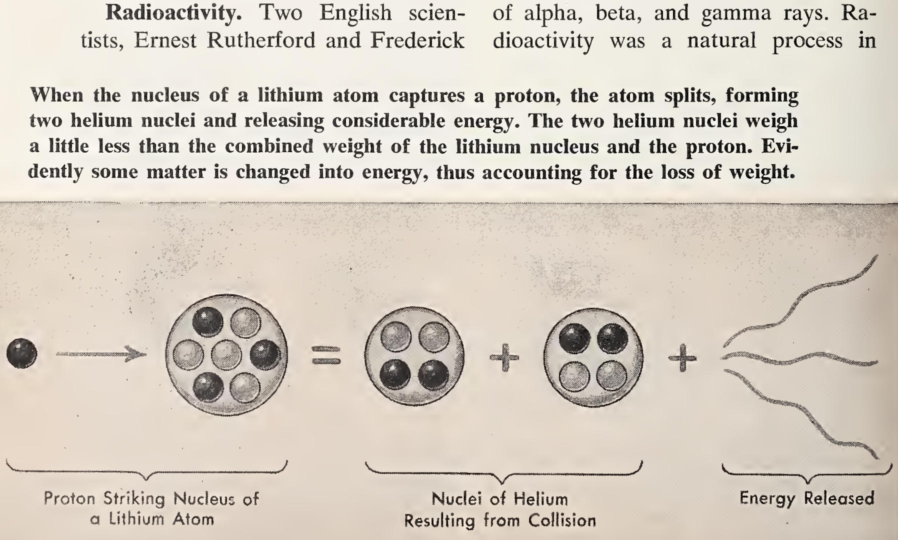
Radium was found to have a great many unusual properties. It would cause certain substances to glow in the dark. It produced enough heat to raise its own weight of water from freezing to boiling in an hour. Because it quickly affected photographic plates, it made pictures similar to X-ray pictures. It killed microorganisms placed near it in a very short time, and was also found to be useful in the treatment of cancer. Radium was a very unusual element and seemed to be supplying energy continuously without ever wearing out.

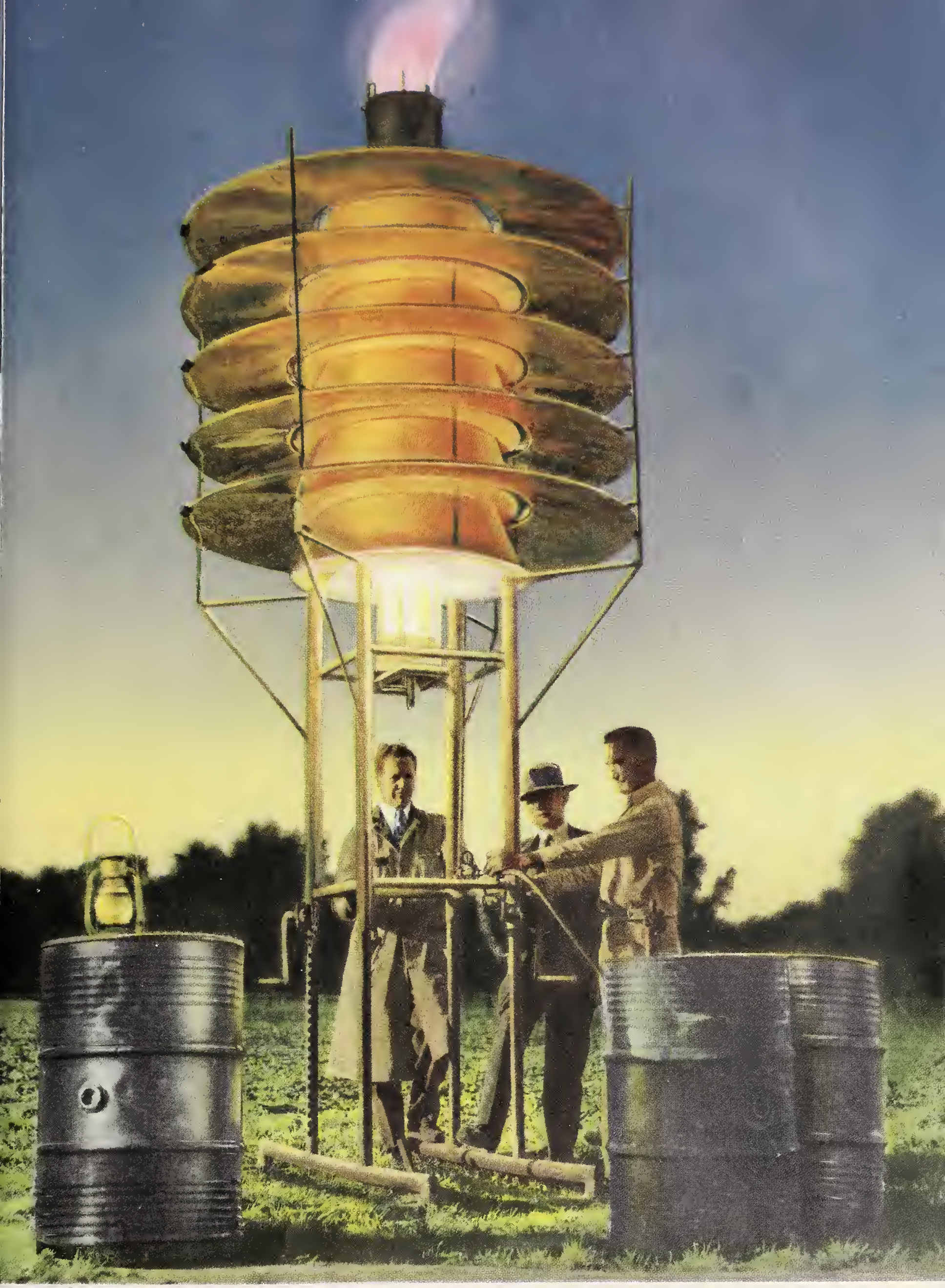
Radioactivity. Two English scientists, Ernest Rutherford and Frederick Soddy, who were working at McGill University in Canada, decided to see whether they could determine what was actually taking place in radium. Together with other scientists working on this problem, they finally discovered that radium was giving off three types of rays, called *alpha, beta,* and *gamma* rays, as shown on page 503. The process radium was undergoing to enable it to give off the three types of rays is called *radioactivity*.

Further study revealed that as radium released its rays, it changed from one element to another, until finally it lost its radioactivity and became one type of lead. Since an atom of lead weighs less than an atom of radium, it was assumed that some of the matter of the radium atom had been changed into energy. During this process, a tremendous amount of heat was given off. However, the change from radium to lead is so slow that the heat is not produced fast enough to be of any practical value.

Significance of radioactivity. There could be only one explanation for radioactivity. The element radium was radiating its matter away in the form of alpha, beta, and gamma rays. Radioactivity was a natural process in

When the nucleus of a lithium atom captures a proton, the atom splits, forming two helium nuclei and releasing considerable energy. The two helium nuclei weigh a little less than the combined weight of the lithium nucleus and the proton. Evidently some matter is changed into energy, thus accounting for the loss of weight.


Proton Striking Nucleus of a Lithium Atom
Nuclei of Helium Resulting from Collision
Energy Released



Michigan State College, Wilbur M. Nelson

An infrared heating device used to protect crops from frost damage. The oil burner heats the discs, causing them to give off infrared rays which warm the crops directly rather than the air surrounding them.

Steuben Glass, Inc.

Glass has those properties which make it possible for experts to shape it into objects of great beauty, like the fine vase this glass blower is making.

which atomic energy was being released. If scientists could duplicate this process, they could then tap the tremendous store of potential atomic energy for their own use.

In 1919 Rutherford suggested that it might be possible to change one element into another by bombarding its atoms with the alpha particles given off by radium. To test his idea, Rutherford bombarded the atoms of nitrogen gas with alpha particles of radium. By this process he changed nitrogen into oxygen. Here indeed was a milestone of science.

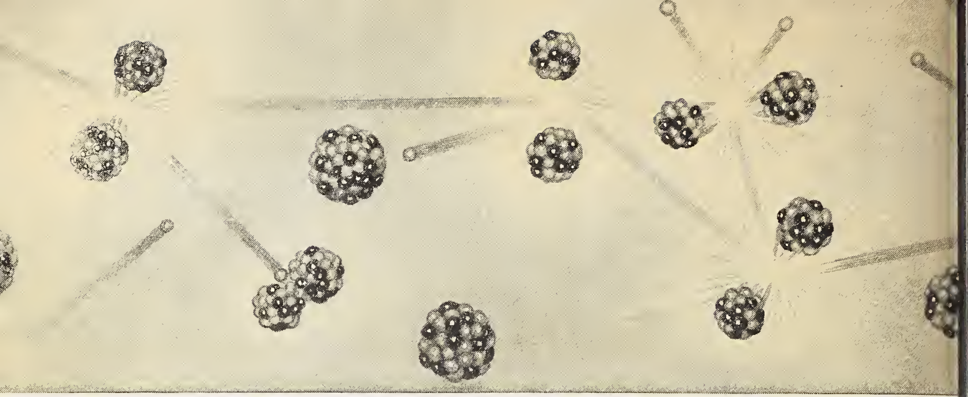
The cyclotron. Rutherford's experiments proved that one element could be changed into another. Scientists believed that by increasing the speed of the bombarding particles, they might change still other elements. Several types of machines, called *accelerators,* are being successfully used for this purpose. Ranging from the least to the most powerful, these machines are known as the *Van de Graaf generator,* the *cyclotron,* the *cosmotron* (see page 495), and the *Bevatron.* The Bevatron gives particles about 1,000 times as much kinetic energy as the Van de Graaf generator. Scientists are hoping to build even more powerful accelerators in the immediate future.

The neutron. For many years scientists had suspected that there was a particle in the nucleus of many atoms similar in size to a proton, but carrying no electric charge. In 1932 an English scientist, James Chadwick, bombarded atoms of the metal beryllium with alpha particles, and found that a new particle, a neutron, was given off.

Splitting an atom. In 1932 two English scientists, J. D. Cockroft and E. T. S. Walton of Cambridge, England, bombarded atoms of the metal lithium with protons. The lithium atom was broken into two parts, each part being the nucleus of a *helium* atom. Furthermore, energy was released when the lithium atom broke apart. Careful investigation showed that the two helium nuclei formed did not weigh quite as much as the lithium atom from which they came. Evidently some of the lithium had been changed into energy. There was no longer any question but that matter could be changed into energy.

Splitting uranium atoms. In 1934 Enrico Fermi, an Italian scientist, believing that the recently discovered neutrons might make good atomic bullets, began a series of experiments in which he bombarded uranium atoms with neutrons. Up to this time, one of the biggest problems was to hit the nuclei of the atoms being bombarded. There was so much space in the atom that the atomic bullets rarely hit a nucleus. Fermi discovered that if neutrons were slowed down, a much greater percentage of hits could be achieved. By bombarding uranium atoms with slow neutrons, he succeeded in making a new element not then found in nature. This element was called *neptunium.*

In 1939 Professor Otto Hahn and his associates, Lise Meitner and O. R. Frisch, working at the Kaiser Wilhelm Institute in Berlin, reported the actual splitting of uranium atoms (see page 506). By bombarding uranium with neutrons, they produced an atomic explosion on a small scale. The results of this work were made available to scientists all over the world. For the first



Chain Reaction. When a uranium atom undergoes fission, the extra neutrons expelled break up other atoms with release of enormous energy. This drawing illustrates how such a chain reaction might occur.

time, tapping and using atomic energy were within the realm of possibility. The illustration above shows what happens when one kind of uranium atom splits, that is, undergoes *fission.*

The atomic pile. It occurred to Dr. Fermi that the extra neutrons expelled by a uranium atom when it underwent fission might be used to break other atoms. Their neutrons could be used in turn to break still others. This process could continue as long as a sufficient number of uranium atoms are present. The way this process, called a *chain reaction,* might be carried out is shown above.

A chain reaction is responsible for the burning of ordinary fuels once they have reached the kindling temperature. The heat resulting from the oxidation of some of the molecules excites other molecules to oxidize, and so the oxidation maintains itself until the fuel is gone. A similar chain reaction with uranium would make it possible to use the uranium as a source of energy.

A device had to be built to test Fermi's idea that a chain reaction could be used to obtain energy from uranium. The first successful device for this purpose was constructed at the University of Chicago in 1942 under Dr. Fermi's supervision. This device, originally called an *atomic pile,* consisted of pure uranium and uranium oxide imbedded in blocks of graphite.

The function of graphite was to slow down the neutrons, because it had been found that slow-traveling neutrons caused fission more effectively than fast-moving ones. Strips of cadmium metal were placed in the pile to absorb some of the neutrons and thus control the rate at which the neutrons split atoms in producing a chain reaction. Instruments were installed to measure the amount of energy that would be released by the pile once it was started. When all was in readiness, the cadmium rods were partially withdrawn from the pile. As this was done, the instruments showed that there was an increase in energy from the pile. It was apparent that a chain reaction could be started and controlled in such an atomic pile. For the first time in history, atomic energy had been tapped so that its rate of release was under man's control.

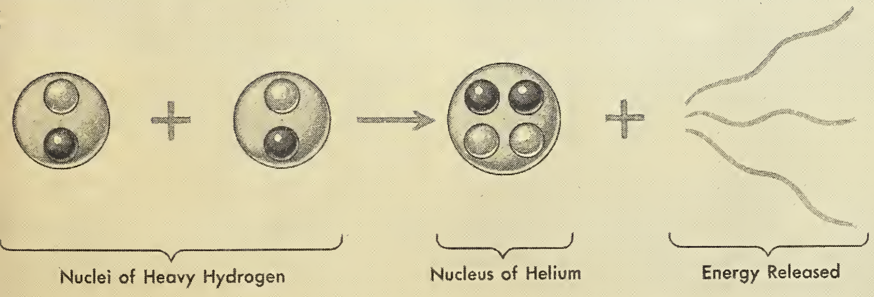
Atomic energy from fusion. The production of atomic energy so far described results from fission in which heavy elements break into parts, with some matter being converted into energy in the process. It is also possible to release atomic energy by forcing hydrogen atoms to combine to form a helium atom (see below). This process is called *fusion.*

Scientists have known for some time that the sun and other stars produce their energy by fusing hydrogen into helium. However, their calculations showed that the process could not occur at temperatures less than about 20,000,000° C. This temperature so far exceeded any that man could produce that there was little thought given to trying to release atomic energy by fusion. Then came the fission atomic bomb with its 150 million C° for perhaps a millionth of a second. Could this bomb be used to "trigger" a super fusion, or hydrogen, bomb? In November, 1952, the United States exploded its first full scale H bomb on a small island, about a mile wide, called Elugelab, in the Pacific Ocean. In an awesome blast, estimated to be equal to that from 5 million tons of TNT, the island was blown out of existence. The sea rushed in to fill a crater 1 mile wide and 175 feet deep where Elugelab had formerly stood. Then on March 1, 1954, another H bomb was set off by the United States. It proved to be even more powerful than the first. Its blast was estimated to be equal to 15 million tons of TNT or about 750 times as great as the fission atomic bomb which shattered Hiroshima, Japan, during World War II. A single bomb of this power would almost completely demolish any city in the world.

Why are H bombs so powerful? There are two reasons. First, fusion develops more energy per pound of material than fission does. Second, a fission bomb cannot contain more than a few pounds of uranium or plutonium or it will explode itself automatically. Thus its size is limited. But no matter how large a fusion bomb is made, it will not explode until its temperature is raised to 20 million C° by the fission bomb which triggers it. There is, therefore, no natural limit to the size of a fusion bomb. Its size is limited only by those who make it.

These discoveries have introduced man to a new age. He has at his command almost unlimited amounts of energy from atomic fuels rather than

Two nuclei of heavy hydrogen (ordinary hydrogen with a proton added to the nucleus) may, under terrific heat and pressure, fuse to form a helium nucleus. Some matter is changed to energy in the process since the helium nucleus weighs less than the two nuclei forming it.



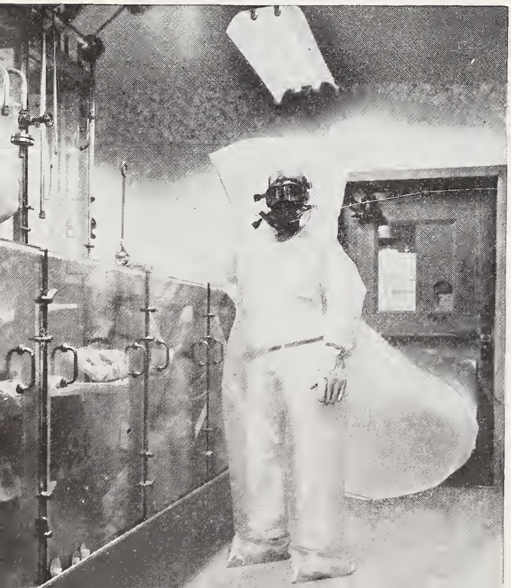
fossil fuels. Power plants depending upon fission are being rapidly developed (see page 509). If man can learn to use fusion for power, one scientist estimates that the hydrogen in a pint of water would yield more energy than 1,000 tons of coal. There seems to be little doubt that for the first time in his history man has available to him enough power to either destroy his civilization or to raise the living standards of all people higher than he had ever before dared hope.

USES OF ATOMIC ENERGY

The atomic bomb. When a fission type atomic bomb explodes, the heat near the center of the explosion approaches that of the sun. It is sufficient to turn steel into a vapor. The heat also makes the air expand rapidly, thus causing a great deal of damage. Particles of the lighter elements produced when the atoms are split are hurled outward from the center of the blast at speeds almost equal to that of light. Even though these particles are small, they possess great amounts of kinetic energy when traveling at such high speed, which adds to the damage done by the bomb. They are also radioactive and are dangerous to living things upon which they settle.

Not a man from Mars! This is a protective plastic suit worn to protect people in certain types of work on atomic energy projects. Note the air filter to prevent inhaling radioactive dust. The "train" in the back is a flexible plastic tunnel leading from the suit to the opening in the wall.

General Electric Company



Radiant energy (gamma rays) is given off when the bomb explodes. Many of the deaths resulting from the atomic bomb were caused by these rays. Scientists are still studying the extent to which people living in the bombed areas in Japan during World War II are suffering injury from these rays.

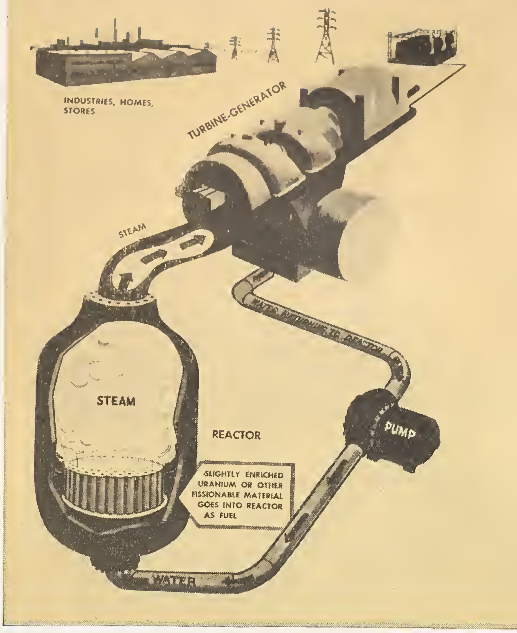
Finally, the shower of neutrons coming from the explosion makes the area around the explosion radioactive. This makes it dangerous for people to move into the bombed area until the radioactivity has had time to die away. Since the fusion bomb is triggered by a fission bomb, it increases the effects just described by the additional energy released by the fusion action. Experts estimate that a fusion bomb similar to the one exploded by the United States on March 1, 1954 (see page 507) would produce complete destruction 4½ miles in every direction from the point at which it exploded, and moderate destruction from between 4½ and 10 miles in all directions.

Tracer elements. Until 1934 the only known radioactive materials were those such as radium, that were found naturally in the earth. In that year, the

Curies' daughter Irène and her husband Frédéric Joliot announced that they had succeeded in producing radioactive elements in the laboratory. They had found that many of the lighter elements, such as aluminum, magnesium, and boron, when bombarded with alpha rays, remained radioactive for varying amounts of time. Scientists recognized these radioactive elements as important aids to research and medicine. They were called *tracer* elements because they could be traced by their radiations with a Geiger counter (see page 88) or by their effect on a photographic negative.

Although tracer elements were recognized to be of great importance, their use was limited by the fact that they were expensive to produce. True, they could be made with a cyclotron, but operating a cyclotron was costly. With the successful development of the atomic pile, now known as a *nuclear reactor,* the production of tracer elements became a simple matter. Almost any element becomes radioactive when left inside a nuclear reactor for a short time. Tracer elements are now prepared in large quantities.

Scientists are using tracer elements to discover how a number of biological processes not yet completely understood take place. For example, they do not yet understand exactly how photosynthesis is carried on by green plants. If they understood it, they might manufacture our foods from carbon dioxide and water. When this is done, we will no longer be dependent on green plants for our food supply. Tracer elements are being pressed into service to help solve the problem of photosynthesis. Carbon dioxide made with radioactive carbon is made available to the plant. It is hoped that by following the tracer carbon dioxide in the green plant, its role in food manufacture can be learned.

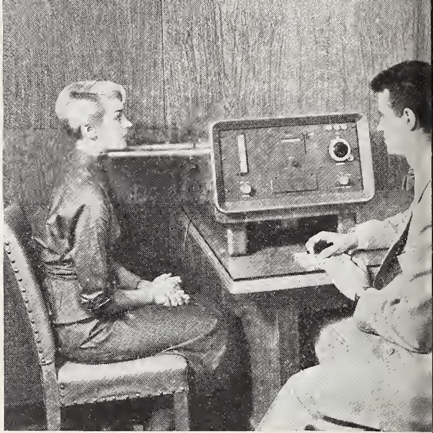

INDUSTRIES, HOMES, STORES
TURBINE-GENERATOR
STEAM
WATER RETURNING TO REACTOR
STEAM
REACTOR
PUMP
SLIGHTLY ENRICHED URANIUM OR OTHER FISSIONABLE MATERIAL GOES INTO REACTOR AS FUEL
WATER

General Electric Company

Atomic energy from uranium can be used to produce electricity for homes and industries. This is one of the many constructive uses to which atomic energy can be put.

Tracer elements are also being used to study ways in which different elements are used in the body. For example, it may be important to know how salt is transported and used in different parts of the body. When a patient is fed salt containing radioactive sodium, it is possible to trace the progress of the sodium as it is carried throughout the body. Radioactive iodine is used in determining how well the thyroid gland is functioning.

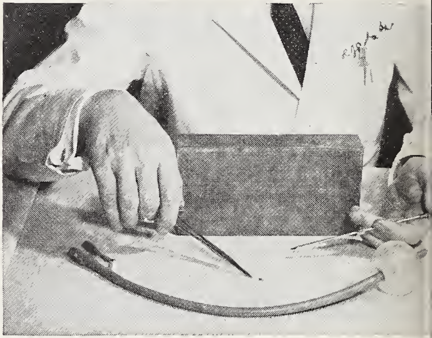
Other uses of atomic energy. Great strides are being made toward the use of atomic energy as a source of power.

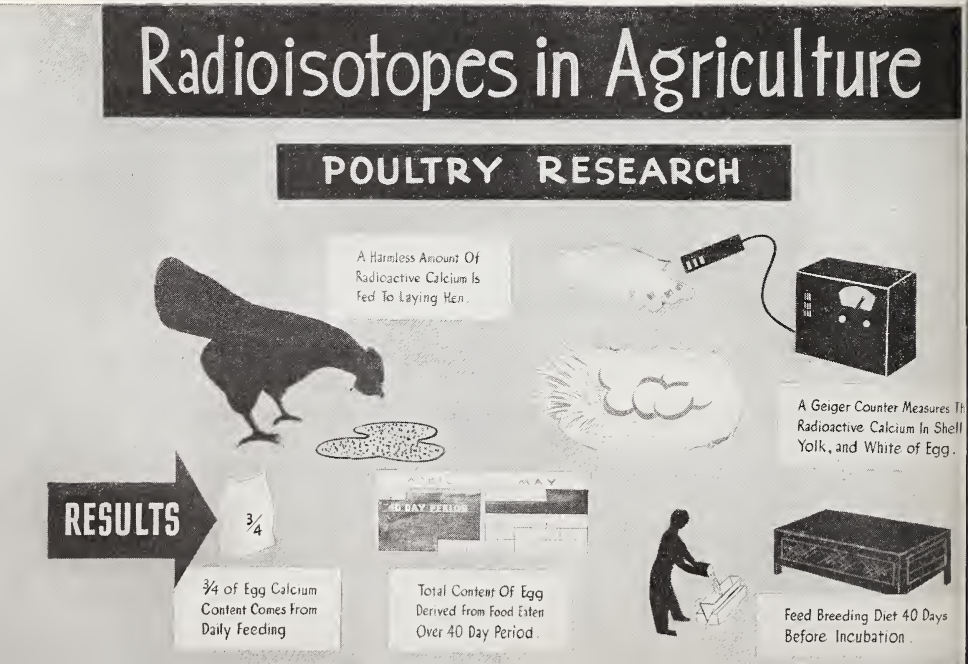


Nuclear Instrument & Chemical Corp.

Scientists are using tracer elements in medicine to discover and treat certain illnesses of man, and in agriculture to improve the food supply. Above, radioactive iodine is given a patient whose thyroid activity is then measured. At right, a tiny pellet of radioactive substance used in X-ray treatment of cancer. Below, the results of research in agriculture, which can be used to improve poultry.

Right: Lila Motley League and Hospital for Joint Diseases
Below: Oak Ridge Institute of Nuclear Studies, Inc.



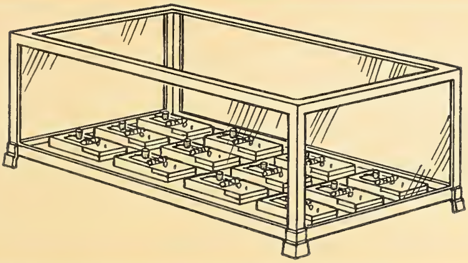

Radioisotopes in Agriculture
POULTRY RESEARCH
A Harmless Amount Of Radioactive Calcium Is Fed To Laying Hen.
A Geiger Counter Measures Th
Radioactive Calcium In Shell
Yolk, and White of Egg.
RESULTS
3/4
3/4 of Egg Calcium Content Comes From Daily Feeding
40 DAY PERIOD
MAY
Total Content Of Egg Derived From Food Eaten Over 40 Day Period.
Feed Breeding Diet 40 Days Before Incubation.

The United States has one submarine, *The Nautilus,* powered by atomic energy. The construction of the first atomic power plant for the generation of electricity was begun at Shippingport, Pennsylvania, in September, 1954. The day this plant begins to deliver electricity to the power lines (probably in 1957), man will be well on the way toward the successful use of a new fuel, uranium, for the production of the tremendous amount of electricity needed for his modern, industrial civilization.

SUMMARY

The development of atomic energy was possible because of the discoveries made by scientists working in laboratories located in many different countries of the world. It also demonstrated the effectiveness of the scientific method in solving many problems. Atomic energy differs from other sources of energy in that it does not originate in radiant energy from the sun, but results from fission or fusion of certain elements. The release of atomic energy adds to our potential source of energy.

OBSERVATION



What to observe. A simple type of chain reaction.

How to observe it. Obtain enough spring-type mousetraps to cover the bottom of an empty aquarium. Place the mousetraps in the aquarium, and carefully set each one with a size 0 cork resting upon the tripper of each trap. After the traps are all set, drop a single cork on one of them. Observe the results. What do the mousetraps represent? What do the corks represent?

Interpretation of your observation. Write a single sentence stating how a chain reaction takes place.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The ray given off by radium that is similar to X-ray is called (a) an alpha ray; (b) a beta ray; (c) a gamma ray; (d) a neutron ray.
2. The atoms that were first split by man were atoms of (a) uranium; (b) lithium; (c) thorium; (d) plutonium.
3. The splitting of an atom into two parts is called (a) a chain reaction; (b) radioactivity; (c) fission; (d) an explosion.

4. Elements which can be followed because of their radioactivity are called (a) dangerous elements; (b) chemically active elements; (c) tracer elements; (d) atomic elements.

5. Atomic energy has been made possible through the work of (a) American scientists only; (b) scientists from many countries; (c) English and Italian scientists only; (d) English-speaking scientists only.

CHAPTER ACTIVITIES

REVIEW POWER

1. You have learned that the two main types of engines in use are internal-combustion and external-combustion engines. Several kinds of engines are listed below. On your answer sheet, beside the number of the engine, write an **E** if the engine is an external-combustion type and an **I** if it is an internal-combustion type. **Do not write in your textbook.**

1. Steam engine with a piston that moves back and forth
2. Gasoline engine used in automobiles
3. Diesel engine used in large trucks
4. Steam turbine used in electric power plants
5. Jet engine used in airplanes
6. Rocket engine

2. Below are listed the strokes of a four-stroke cycle engine. On your answer sheet, write the strokes in order of their occurrence, beginning with the stroke in which the fuel enters the piston.

1. Exhaust
2. Intake
3. Power
4. Compression

FORM A GENERALIZATION

Three important generalizations developed in this chapter are listed below. Following each is a list of statements which may or may not illustrate the generalization. On your answer sheet, beside the number of the generalization, write the letters of those statements which illustrate that generalization.

1. Transformation of energy enables us to utilize the sources of potential energy in the world.

   a. Energy is the capacity to do work.
   b. An automobile uses gasoline for fuel.
   c. The force of falling water often turns generators that produce electricity.
   d. Green plants use sunlight in manufacturing food.
   e. Kinetic energy is the ability of an object to do work because it is moving.
   f. Some clocks have numbers that glow in the dark.

2. Simple machines do not save work but add to the convenience with which we do much of our work.

   a. More work is put into a simple machine than it is possible to obtain from it.
   b. Some simple machines multiply the force which we exert.
   c. The work done in lifting an automobile with a hand-operated jack is greater than that done if the automobile were

lifted vertically to the same height.
  - d. The food we eat is said to possess chemical energy.
  - e. An inclined plane is often used when loading a heavy object into a truck.
  - f. Some simple machines change the direction in which a force acts.

3. Engines are rapidly replacing man and animals as a source of power in our modern civilization.
  - a. Many farmers use tractors rather than horses to do their farm work.
  - b. Many engines are of the four-stroke cycle type.
  - c. Ski tows are used to haul skiers to the top of ski runs.
  - d. Many bicycles are equipped with small gasoline engines.
  - e. A Diesel engine requires neither a carburetor nor an electrical system.
  - f. A power shovel is often used to excavate cellars for new houses that are to be built.

UNIT ACTIVITIES

APPLY YOUR KNOWLEDGE

Four of the generalizations developed in this unit are listed below, followed by a number of statements related to the use of energy and the development and use of power. In the proper place on your answer sheet, beside the letter of each statement, write the number of the generalization illustrated by that statement.

GENERALIZATIONS

1. Simple machines are useful because they multiply force, change the direction of a force, or increase the speed of or distance through which a force acts.
2. The efficiency of machines can be increased by polishing surfaces, substituting rolling for sliding friction, and by lubrication.
3. Work can be done with a force developed from the kinetic energy of molecules.
4. Energy is released when atoms of some elements undergo fission.

STATEMENTS RELATED TO USE OF ENERGY AND POWER

a. A hammer can be used to pull nails from a board.
b. An automobile should be greased at regular intervals.
c. The cylinders of some automobile engines are as smooth as mirrors.
d. The heat from an atomic-bomb explosion is sufficient to turn steel located near the center of the explosion into vapor.
e. Steam engines can pull trains.
f. Many automobile engines develop 100 horsepower.
g. An automobile engine is damaged if it is operated without a supply of oil.
h. Food can be cut easily with a sharp knife.
i. A golf ball can be driven several hundred yards with the proper club.
j. Players often hit the baseball farther than they can throw it.

k. Airplanes equipped with jet engines can travel at high speeds.
l. Rockets have been sent into the stratosphere.
m. Heavy objects are often placed on rollers when they are being moved.
n. Radioactive elements can be traced when they are taken into the body.
o. An atomic-bomb explosion will destroy buildings at a considerable distance from the center of the explosion.

MAKE DRAWINGS TO LEARN MORE

1. To show the position of the piston and valves in each of the strokes of a four-stroke cycle engine
2. To illustrate the way jet and rocket engines develop a force
3. To show various types of simple machines in use
4. To illustrate several examples of the transformation of energy
5. To show how an atomic pile operates

REPORT ON WORK AND POWER

1. Types of engines used in automobiles
2. Water as a source of power
3. The first steam engine
4. Jet engines for aircraft
5. Tracer elements in medicine
6. Tracer elements in industry
7. The cyclotron
8. Atomic energy for power
9. Labor-saving machines used in the modern home
10. Methods of measuring horsepower of engines

READ ABOUT WORK AND POWER

Beeler, Nelson F., and Branley, F. M. *Experiments with Atomics*. New York: Thomas Y. Crowell Company, 1954.

Experiments that are easy to do.

Burnett, Will R. *Atomic Energy—Double-Edged Sword of Science*. Columbus: Charles E. Merrill Co., Inc., 1949.

A complete nontechnical booklet on atomic energy covering the nature of the atom, atom splitting, wartime uses, peacetime uses, and control.

Lewellen, John. *Atomic Submarine*. New York: Thomas Y. Crowell Company, 1954.

Author explains atomic submarine largely by comparing it with earlier types. Provides history of submarines.

Leyson, Captain Burr W. *Modern Wonders and How They Work*. New York: E. P. Dutton and Company, Inc., 1949.

Deals with some of the concerns of science, such as bombs, rockets, military jets, supersonic speed, guided missiles, robots, radar, proximity fuse, and space ships.

Potter, Robert D. *Young People's Book of Atomic Energy*. New York: Dodd, Mead & Co., 1952.

Chapters 13 through 18 deal with atomic medicine, the sun as an atomic powerhouse, atomic control of weather, cost of atomic power, and control of atomic energy.

Schneider, H. *Everyday Machines and How They Work*. New York: McGraw-Hill Book Company, Inc., 1950.

An explanation of how all kinds of machines and devices used in the home work—from electric toasters and Yale locks to electric trains and musical instruments.

NACA

A scale model of a jet airplane being tried out in a wind tunnel filled with compressed air. This test will show how the plane will react to atmospheric conditions.

unit 12 TRANSPORTATION AND COMMUNICATION

BACK in the middle of the last century, The Pony Express was famous for speed. It traveled the two thousand miles between St. Joseph, Missouri, and San Francisco, California, in eight to ten days. This was such extraordinary traveling that, although The Pony Express was used for only nineteen months, its name has come down to us as a symbol of speed. Today such travel-time, with its hardships and discomforts, seems plodding. We can reach almost any place in the world in a matter of hours. Towns thirty miles apart, which were once a whole day's journey from each other, are now close enough for casual visits. Daily or hourly commercial traffic between cities in different parts of the world is taken for granted. The world has become, in effect, much smaller.

Distances have also been overcome in another way. No longer must we wait for slow mails in order to communicate with people in distant places. Now Washington can speak to London, Paris, Bombay, or any other distant place in a matter of minutes. Radio, television, and telephone have made the whole world neighbors.

In this unit you will learn how by the use of science we have overcome distance and developed rapid and comfortable transportation, as well as speedy and accurate communication.

Trans World Airlines, Inc.

The modern airplane contains a maze of instruments and indicators each contributing its part toward safe flight under all conditions.

chapter 27 TRANSPORTATION

If you watch the traffic on a heavily traveled highway or at a busy railway station, a large airport or seaport, you will realize how important are the vehicles that link all parts of the nation as well as nations of the world. These vehicles transport people, goods, and services to make our lives more comfortable. The early colonists in America depended largely on water transportation, making it necessary for them to settle along the eastern coast and on the banks of rivers up which they could sail. Railroads, then motor vehicles, and finally airplanes were developed and improved through the use of science. They changed our way of living by providing fast, dependable transportation over great distances.

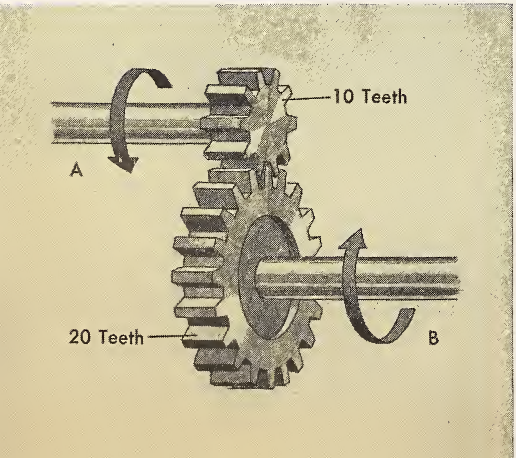
PROBLEM 1. How have we improved transportation by motor vehicle and rail?

IMPROVEMENTS IN AUTOMOBILES

Engine improvements. At the beginning of the twentieth century *motoring* was a great adventure. In automobiles that resembled the carriages of the day, and so were called "horseless carriages," passengers were exposed to the dust of the roads and the whims of the weather. The large, small-rimmed wheels sank deep into the soft roads, and the vibrations of the engines meant neither power nor dependability, but only discomfort. Hand-cranking was necessary in order to start the engine, which often failed to start at all.

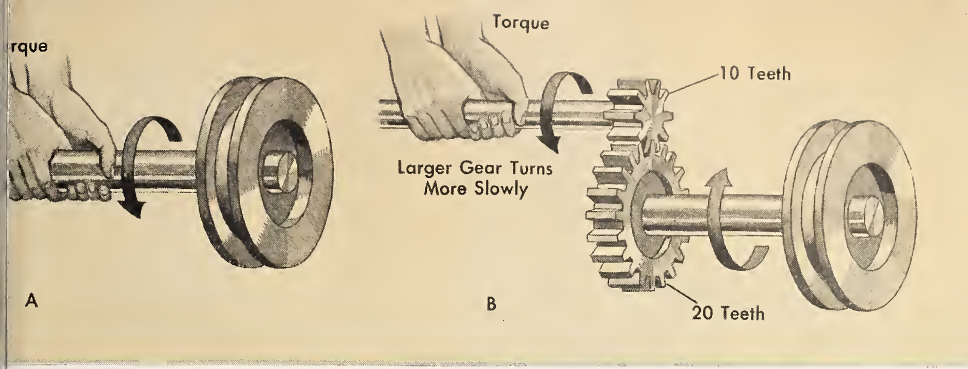
Scientific study and experimentation have changed all that. One of the biggest improvements is in the engines. As you remember from Unit 11, the force to drive an automobile, usually called *torque,* is developed by an internal-combustion engine of the four-stroke cycle type. For each power stroke the crankshaft makes two complete revolutions. Such a single-cylinder engine vibrates strongly and delivers force unevenly. By adding cylinders and making each one deliver its power stroke at a different time, it is possible to make the engine run with less vibration and produce a more even flow of power. The more cylinders added, the shorter the time between the power strokes. Today passenger automobiles usually have four-, six-, or eight-cylinder engines, although a few may have as many as twelve or sixteen.

B will turn ½ as fast as A. B will have twice the torque of A. Speed is sacrificed for increase in torque.



Another method of making engines run more smoothly is to use the *inertia* of a heavy wheel. Scientists use the term inertia to describe the tendency of any object to continue to move once it is in motion, or to remain at rest once it has stopped moving. For example, when the brakes are applied suddenly to a swiftly moving automobile, the occupants tend to be thrown forward because of their inertia. When you spin a top, its inertia keeps it spinning after it has been started. To reduce the vibration and help produce even power in an automobile engine, the inertia of a *flywheel* can be used. As it turns rapidly with the crankshaft, the flywheel helps carry the pistons through their nonpower strokes with very little change in speed, thus reducing the vibration.

Torque multiplication. For an automobile to move, the engine torque must be transmitted to the driving wheels. Then, too, torque demands are often greater than the engine can deliver when it is coupled directly to the driving wheels. For example, more torque is required to start an automobile moving than to keep it moving



In A, the torque is applied directly to the wheel. Since there is no change, or conversion, it is said to be delivered in a 1 to 1 ratio. In B, the torque is changed in direction and multiplied by 2 by the gears. Thus the gears are *torque converters* and deliver torque in a 2 to 1 ratio. The torque is increased at the speed of rotation.

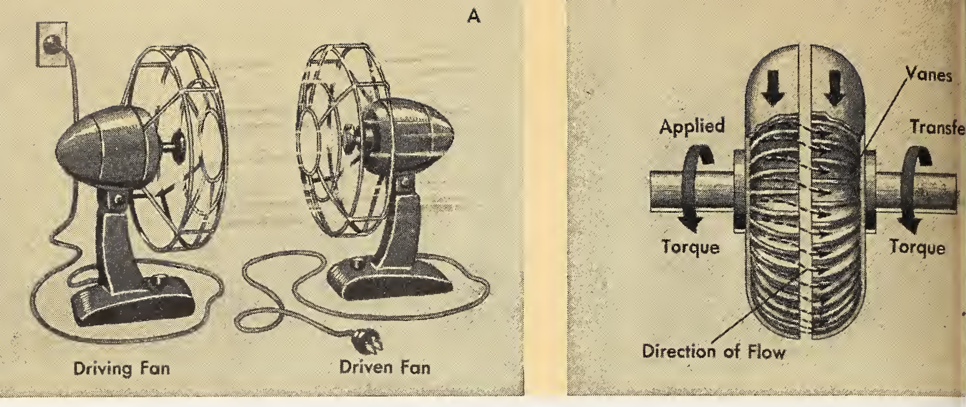
because the automobile's inertia must be overcome. It also requires more torque to go up hill than to drive along a level road. A device for changing torque is called a *torque converter*. Two methods for changing torque are widely used in automobiles. One depends upon gears, and the other uses an enclosed fluid, oil. Some automobiles use only gears while others use both methods.

Gear torque converters. A gear is a wheel with teeth around its rim. Two gear wheels with properly cut teeth can be fitted together so that as one is turned it will turn the other, but in the opposite direction, as shown at top of page.

The amount of torque multiplication depends upon the mechanical advantage of the gear system. The mechanical advantage can be found in several ways. One of the simplest is to divide the number of teeth in the driven gear by the number in the driving gear. This method neglects losses caused by friction. In the above example, the mechanical advantage is 20 divided by 10 or 2. Thus, neglecting friction, these gears would multiply the torque by 2. By the proper selection of gear size, torque can be increased, but always at a reduction of speed of rotation. The speed of rotation can be increased but always with reduction of torque. By operating the manual gearshift in an automobile, the driver can select different sets of gears that multiply torque to meet the different needs for all types of driving conditions.

Fluid drive. The operation of fluid drive systems depends upon the fact that torque can be transmitted by a moving fluid such as water or oil. This fact can be simply demonstrated, as shown at A on page 520. Some automobiles have used fluid torque transfer, known as *fluid coupling* or *fluid drive,* for many years because it provides smooth torque transfer which helps prevent jerky driving. Fluid coupling does not increase torque.

Fluid torque converters. By changing the design of the fluid coupling members and adding two sets of specially curved blades, it is possible to direct the oil flow so that the speed given the oil by the driving member is increased. This device is called a *torque converter*. The speed increase given the



The air currents will turn the unconnected fan. With two specially designed wheels somewhat like grapefruit halves with the fruit removed and only the dividing membranes left, enclosed in oil, torque can be smoothly transferred from one wheel to the other. This is known as *fluid coupling*.

oil by the torque converter adds to the torque delivered by the driven member. Thus it increases the torque delivered to the rear wheels.

The maximum torque increase with a fluid torque converter occurs when the driving member attached to the engine is rotating much faster than the driven member, which is connected to the driving wheels. This situation exists when the automobile is starting to move. Under these conditions, the converters in use may increase the torque as much as 2.7 to 1, the actual increase depending upon the design of the particular converter. As the speed of the automobile increases, the speed of the driven member gradually approaches the speed of the driving member.

As it does so, the torque transfer is adjusted smoothly and automatically until at a steady car speed under light load the torque transfer is about 1 to 1 (see page 519). Because this change takes place so smoothly, torque converters are used by almost all automobile manufacturers.

Automatic torque transmission. A torque converter smoothly and automatically does much of the torque changing formerly taken care of by the manual gear-shift. By using the converter with gears to provide for reversing and for very high torque demands, and by including a system of automatic controls, designers have been able to eliminate the manual gearshift. Instead, there is a manual selector which is set for the driving range required.

Controlling temperatures of engines. The heat-control system on modern automobiles keeps the engine running at correct operating temperatures. Since the temperature of the fuel burning inside the cylinders of an automobile is extremely high, some of the heat must be carried away to prevent damage to the engine. How the cooling system controls the operating temperature of the engine under all conditions can be learned from a study of the diagrams on page 522. A dial on the instrument panel registers the engine temperature for the driver.

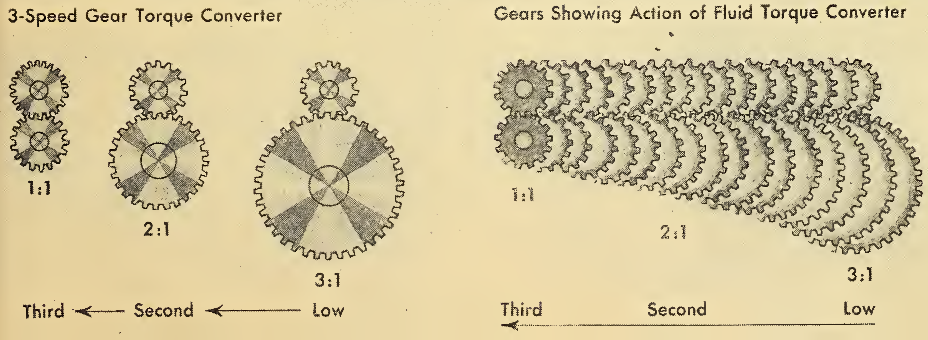
During cold weather, the heat-control system of an automobile presents two important problems for the driver. First the water is likely to freeze, and the expansion resulting from this may break the walls of the engine. To prevent this the water is mixed with some substance, called an *antifreeze,* which will lower its freezing temperature. Glycerine, alcohol, and a chemical called *ethylene glycol* are the most commonly used antifreezes. The second problem created by cold weather is that of keeping the engine warm enough to run efficiently. The most common way to accomplish this is with a thermostat installed as shown on page 522.

The interior of an automobile can be heated by a small radiator connected with the cooling system of the engine. An electric fan forces air past the tubes in this radiator where it is warmed, and circulates throughout the interior of the car. Sometimes warm air from the heater is directed against the windshield to prevent moisture, ice, or snow from sticking to the glass and obstructing vision. Air-conditioning systems for automobiles, such as shown in the drawing at the top of page 523, can be obtained.

Engine fuels. In modern automobile engines, the fuel before it is burned is compressed into a space ranging from one sixth to one tenth of the volume of the cylinder. Such high-compression engines make it possible to obtain the greatest amount of force from the fuel; this is one way the power of modern engines has been increased to over 200 horsepower, as compared to the 12 horsepower of the earliest automobile engines. If the heat produced by the high compression causes the fuel to burn before it is ignited by the spark, the engine will knock, an indication that it is not performing efficiently. The measure of effectiveness of gasoline for use in high-compression engines is known as its *octane rating*. The higher the rating, the more suitable the gasoline is for such engines. Lower-octane gasoline can, however, be treated with *tetraethyl lead* so that it can be used in high-compression engines satisfactorily. Treated gasoline also burns more slowly, thus providing smoother operation of the engine.

Safety features. A speeding automo-

An automobile gear torque-converter (transmission) usually has three forward positions. The automobile is started in low, shifted to second and finally to high for driving. Although the fluid torque converter does not have gears, it behaves somewhat as a large number of gears which automatically adjust themselves to meet the torque demands as shown at B.


3-Speed Gear Torque Converter
1:1
2:1
3:1
Third
Second
Low
Gears Showing Action of Fluid Torque Converter
1:1
2:1
3:1
Third
Second
Low

bile possesses a large amount of inertia. In order to stop, the inertia must be overcome. To do this and bring the car safely to a stop, good, dependable brakes are necessary. Modern automobiles have brakes on all four wheels rather than on two, as the earlier automobiles had. Four-wheel brakes make quicker, safer stopping possible. To avoid the uneven effect often produced by the older brake system of levers, *hydraulic brakes* are now used. Both power brakes and power steering are used on many automobiles. With these systems, force developed by the engine is used to assist the driver in applying the brakes and turning the steering wheel. Thus driving becomes less tiring and safer.

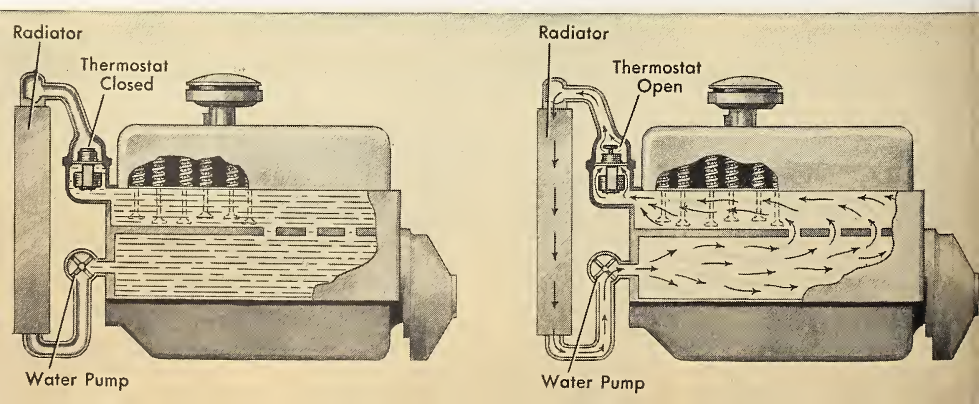
Automobile bodies have been strengthened to add to the safety of the cars. The glass used in the windows and windshield is shatterproof. It is made somewhat like a sandwich with a layer of tough, transparent material placed between two thin layers of glass. The three are securely fastened together. If the glass is struck a sharp blow, the tough material between the layers keeps the broken glass from flying around and striking anyone.

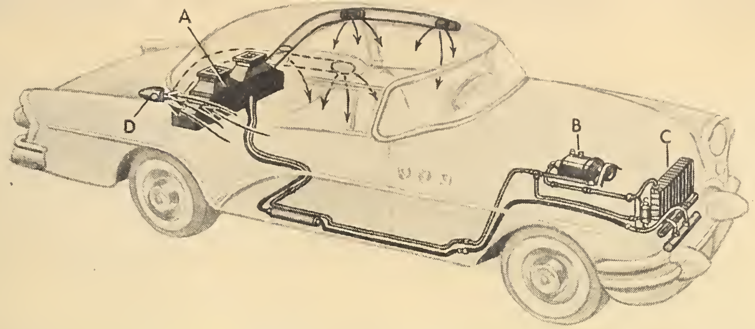
Oil lamps, gas lamps, and electric lamps have all been used on automobiles for night driving. Each was an improvement over the preceding one. *Sealed-beam* headlights are now used on the modern automobile.

Better roads. Highways for safe, rapid automobile transportation should be smooth, wide enough to handle the traffic, and have a hard surface that can be used in all kinds of weather. They should have no steep grades, curves, or obstructions to vision. They should also be well marked with warning signs visible both in daylight and at night. Some of the improvements made in highways are shown on page 525.

Trucks, buses, and small cars. People today are more dependent on trucks and buses than most of us realize. To those living in towns and cities, trucks deliver food and soft drinks, fuel to heat homes, and all kinds of merchandise. To farmers, trucks are an important way to get their produce to markets. Buses in cities and between

The cylinders of an automobile engine are surrounded by water which absorbs the heat of combustion. The hot water is then circulated through the radiator where air cools it. In cold weather a thermostat stops circulation of water (left) when the engine is cold and allows circulation (right) when the correct operating temperature is reached.





An automobile air-conditioner operates like an electric refrigerator. The cooling coils are at A, the compressor at B, and the condenser at C. Outside air enters at D (one opening on each side), is filtered, cooled, and forced through the openings in the ceiling. Air from inside the car enters the registers back of the rear seat, is filtered and re-circulated.

cities are an inexpensive means of travel.

Smaller trucks operate much as automobiles do, many even having the same kind of engines. Truck body and frame are built stronger to carry the heavy loads hauled in them, and many trucks have additional wheels and larger tires than passenger cars. The extra force needed to haul large loads is obtained by extra gears in the transmission. Many of the vehicles used for hauling large loads are *semitrailers;* others have been developed for many special purposes.

A number of small motor vehicles are also used in transportation: "midget" automobiles, motorcycles, motorbikes, and motor scooters. The chief advantage of these is the fact that they provide rapid transportation economically, since they cost less to buy and operate than standard-size cars. They are also easier to handle in heavy traffic, and make parking less of a problem in our crowded cities.

IMPROVEMENT IN RAILROADS

Early trains. The first railroad in the United States was built in 1826 to haul granite from a quarry to a river wharf more than three miles away. Of the railroads now in operation, the Baltimore and Ohio is the oldest, having begun operation in 1829. In 1832 steam engines began to replace horsepower, and the 61-mile trip from Baltimore to Frederick, Maryland, could be made by steam train, but it required a full day of uncomfortable travel.

When rapid land transportation capable of carrying large loads became necessary for the development of rich natural resources in the West, railroads met the need. Within thirty years after the first railroad began operation, 30,626 miles of road had been constructed. Today about one third of the total railway mileage in the whole world is in the United States.

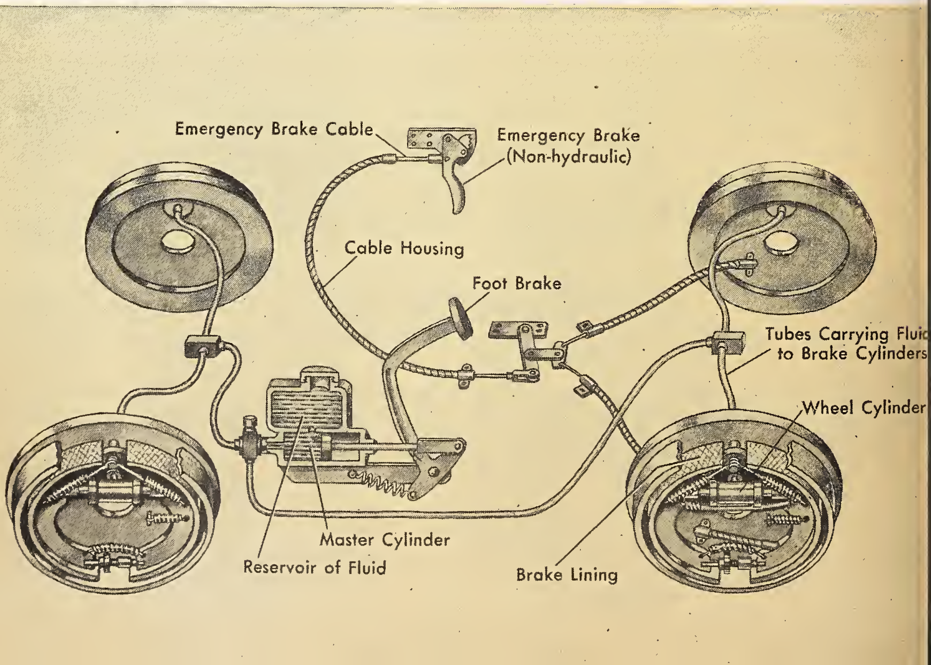
Types of locomotives. The first type of locomotive developed, the steam locomotive, was the only kind used until about 1900. Some locomotives are driven by two steam engines like that shown on page 498. They are mounted down close to the rails, each engine driving from two to five large wheels called *drivers*. The boilers are of the *fire-tube* type in which the hot gases from the fire pass through tubes surrounded by water. The average steam locomotive has about a mile of such tubing. The heat from the tubes changes the water to steam. The controls for operating the locomotive are mounted in the cab, while the fuel and water are carried in a small car called a *tender*.

The pulling force of locomotives is limited not by the total force they can produce, but by the amount of friction between the drivers and the rails. The pulling force is usually equal to about one fourth of the load supported by the drivers. Some larger locomotives can produce a pulling force of more than 25 tons.

In electric locomotives, the second type, the driving force is obtained from large electric motors connected with the driving wheels. The locomotive does not develop its own electricity, but obtains it through an overhead line or separate rail from an outside electric-power system.

The third type, the Diesel-electric locomotive, uses a Diesel engine to drive electric generators, which in turn furnish electricity for electric motors to drive the locomotive. Diesel-electric locomotives are rapidly replacing the older steam locomotives.

A fourth type, the gas-turbine-elec-



Hydraulic brakes of an automobile. When the foot pedal is pushed forward, pressure is exerted on the fluid in the master cylinder. This pressure is transmitted with equal force throughout the fluid in the tubes leading to the wheel cylinders. The pressure on the fluid in the cylinders forces pistons out and applies the brakes.

Connecticut Highway Department

The old and the new in highway construction. At left is shown U. S. Route 1 at Darien, Connecticut, at right a cloverleaf interchange between Merritt Parkway and Main Avenue (U. S. Route 7) in nearby Norwalk, Connecticut.

tric, is coming into use for fast, long-haul freight service. It is similar to a Diesel-electric with a gas turbine substituted for the Diesel engine.

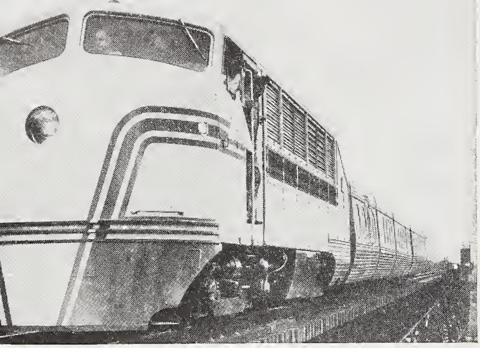
Freight cars. Many types of railroad cars have been developed. Refrigerator cars for hauling fresh fruit, vegetables, and meat have thick walls, floors, and ceilings with dead-air spaces to provide insulation. They are refrigerated in hot weather and heated in cold weather to protect the contents.

Livestock are hauled to market in stock cars so designed that there is an adequate amount of ventilation for the animals. Other cars have been constructed for such special cargoes as airplane wings, coal, ore, gasoline, oil, gas, and various kinds of machinery (see page 489).

Passenger cars. Passenger trains also have several types of cars, each designed to contribute to the comfort and convenience of the passengers, and all made possible by the use of science. Modern cars are attractively decorated with pleasing colors; lighting without glare is adequate for all passengers. Double-paned windows with an air space between the panes are tightly sealed so that they will not frost over in cold weather. Because an air-conditioning system keeps the cars filled with filtered, fresh air of the proper temperature at all times, the windows do not need to be opened for ventilation.

There are several types of special passenger cars. In some chair cars, seats can be lowered almost to a reclining position. The Pullman cars have seats which can be converted into beds, with an additional bed that can be pulled out over each seat. The beds are called *upper* and *lower berths*. Bedrooms and roomettes are also available. Special dining cars serve well-cooked meals, and a lounge car gives passengers the convenience of a living room with a radio, a library, and desks.

Railway tracks. The tracks consist of two steel rails attached to wooden crossties set in gravel or some other material to hold them in place. They rest on a foundation called a *roadbed*. One of the costliest operations in build-



ACF Industries, Inc.

A new demonstrator train, low and lightweight, hugs the rails so that it can take curves without slowing down.

ing a railroad is the construction of a suitable roadbed with as little grade as possible. The ideal roadbed rises not more than one foot in each 100 feet, but this 1 per cent *grade,* as it is called, has not always been possible.

As high-speed trains were developed, the weight of the steel rails was increased from about 40 pounds per yard to as much as 120 pounds per yard. Heavier crossties also were necessary. Crushed rock was found to be the best material for holding the crossties in place. Many roadbeds had to be strengthened, and others had to be rebuilt to avoid the curves too sharp for high-speed trains. The outside rail on the curves had to be raised slightly higher than the inside rail to enable trains to round curves at high speed.

Track inspection. Since railroads are concerned about the safety of passengers and freight, they make frequent inspections of their equipment. The rails are frequently inspected with modern scientific devices such as the especially equipped rail inspection car. The car travels at about 6 miles per hour. Electricity produced by a generator is conducted into the rails by copper brushes which slide along them. A *searching unit* composed of coils of wire is mounted midway between the brushes and directly above the rail. As the car moves, a large current of electricity flows through the section of the rail between the brushes.

The magnetic field around the rail induces a voltage in the searching coils which is carried to electronic equipment inside the car. This equipment controls automatic pens marking straight lines on a moving roll of paper. If there is a flaw in the rail, however, the magnetic field changes, thereby changing the voltage in the searching coils and causing the pens to make jogs in the lines. The changes in voltage also cause other equipment to shoot white paint on the rail at the suspected spot. If the spot is considered to have a serious defect by the operator who examines it, it is marked with red paint for the attention of the railroad maintenance crews. Many rails judged defective by this method of detection are replaced by the railroads each year.

Signal, dispatching, and communication systems. In the early days before telegraph and telephone communication, a visual signal system was used to report the progress of a train. White balls on 30-foot poles, visible through a telescope to a signalman three miles away, were hoisted when the train passed. A black ball meant that the train was delayed.

Today electrically operated signal systems are used. The most common type is the *block* system, in which a mile or two of track constitutes a block. The rails are bonded together at the ends so that electricity can flow through the rails from one end of the block to the other. Each block is insulated from the next, and is so wired that when no train is on it, the signal shows green to indicate that the block is clear. When a train enters the block, the wheels and axles form a short circuit between the rails, changing the signal to red to show that the block is occupied. In most systems the signals also show in the locomotive cab so that they can be seen by the engineer when visibility outside is poor. For added safety, in some systems if a train enters an occupied block, the brakes automatically lock, stopping the train until the block is cleared.

Where many trains run over a limited amount of track, the movement of the trains is controlled through a *Centralized Traffic Control* system (see below). With such a system, over 500 trains enter and leave Grand Central Terminal in New York City over just four tracks every 24 hours.

Signal systems are often supplemented by some kind of voice communication. Radio waves have made communication possible at all times between personnel on the trains and between trains. In Chapter 29 such radio communication will be described.

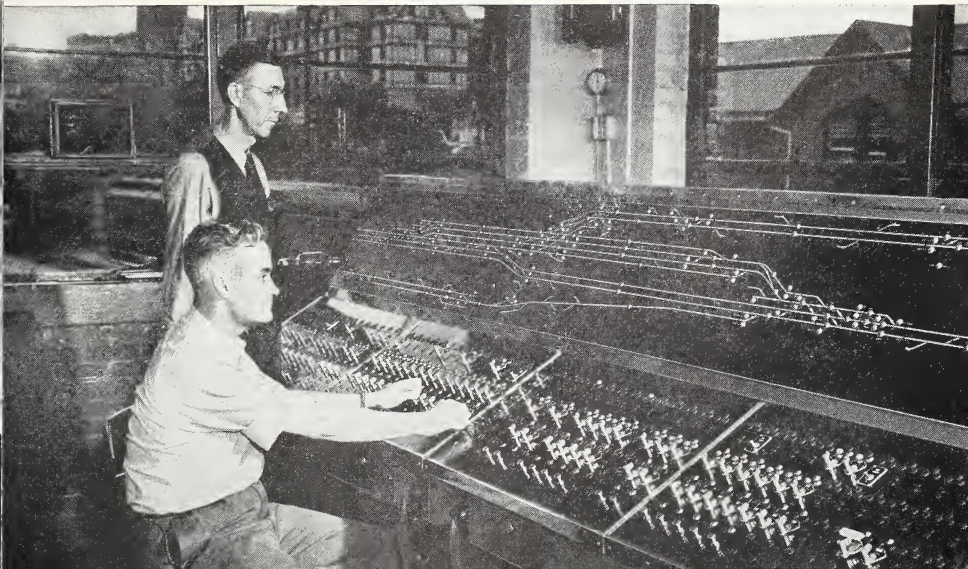
SUMMARY

The development of smooth-running, powerful automobiles which make it easier and more enjoyable to travel, has been achieved through improved engines, more even transmission of power to the driving wheels, better fuels, and safer, stronger automobile bodies. Improved roads have also made traveling at high speeds in all kinds of weather safer. Trucks, buses, and small motor vehicles provide a variety of means of transportation that fit almost any need.

Railroads continue to be one of the most important means of transportation. Most of the locomotives in use

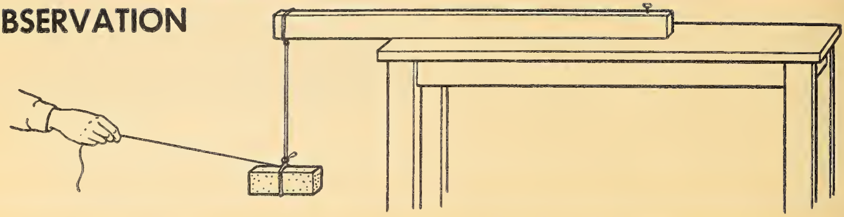
This control board enables railroad men to follow movements of trains by lights on the track diagram at top. Tracks and signals can be controlled by hand-operated switches as these men are doing.

Association of American Railroads



are steam, electric, and Diesel-electric, each suitable under different conditions. Freight cars have been designed to haul different types of freight efficiently. Designs of passenger trains and special signal and communication systems make travel at high speeds safe, convenient, and comfortable.

OBSERVATION



What to observe. The effects of inertia.

How to observe them. Hang a heavy object such as a brick from a strong support with a 2-foot length of sash cord. Tie a piece of sewing thread around the brick. While the brick is hanging motionless, give a sudden sharp jerk on the sewing thread. Did the brick move very much? Tie another piece of sewing thread to the brick. Start the brick swinging by pulling gently on the thread several times. Time the pulls so that the brick swings a little farther with each pull. Do not pull hard enough to break the thread. After the brick is swinging across a distance of a foot or more, hold the thread firmly and try to stop the motion of the brick with it. What happens to the thread?

Interpretation of your observation. Write one sentence stating how inertia is related to stationary and moving objects.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The smoothest driving force is obtained from an automobile engine of (a) four cylinders; (b) six cylinders; (c) eight cylinders; (d) twelve cylinders.
2. Hydraulic brakes are used on automobiles because (a) they are cheaper to make; (b) they apply the braking force equally to all wheels; (c) more braking force can be obtained with them than with other types; (d) they are the newest type of brake.
3. The pulling force of a locomotive is limited by (a) the power of its engine; (b) the amount of fuel it uses; (c) the friction between drivers and rails; (d) the weight of the steel rails.
4. The earliest type of locomotive used was (a) Diesel-electric; (b) steam; (c) electric; (d) hydraulic.
5. Before high-speed railroads could be used, tracks had to be made (a) lighter; (b) heavier; (c) of steel; (d) of wood.

PROBLEM 2. How are ships used for transportation?

IMPROVEMENTS IN SHIPS

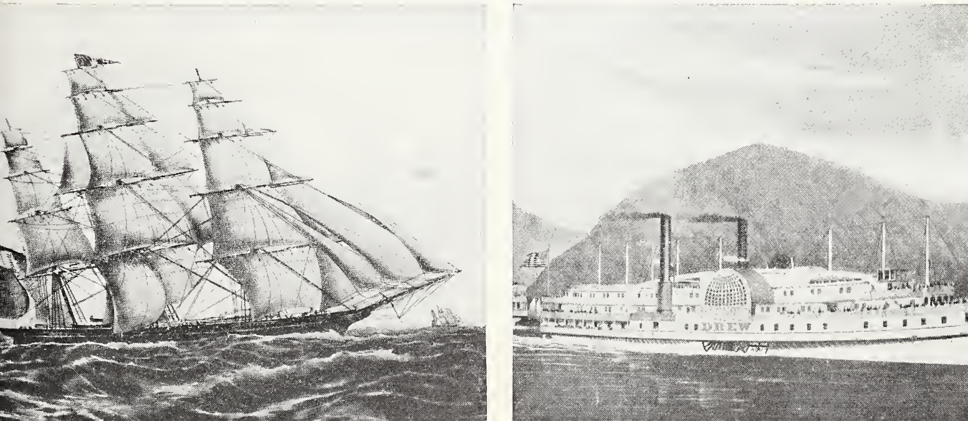
Ancient ships. As early as 6000 B.C. the Egyptians used sailing vessels for sailing with the wind, but to go against it they provided each ship with many rowers. The Romans used slaves to row their warships. Until about 1850 the water transportation of the world was carried on in sailing ships, notable among which were the *clipper ships,* the fast freight-carrying ships of the 1850's (see below). One such ship made a round-the-world trip in 132 days, a record never beaten by a sailing ship.

Steam engines. During the second half of the nineteenth century, the sailing fleets began to decline because of the use of iron and steel in constructing ships, and because of the introduction of steam engines for power. By 1900 most ships were powered with steam engines.

At first the engines were used to turn large paddle wheels on the sides of the vessels (see below). These were later replaced by the *screw propeller,* consisting of two or more curved blades mounted on a shaft turned by the engine, the blades traveling through the water much as a screw turns when it goes into wood. Placed at the rear of the ship, the propellers drive it forward as they rotate. Some large ships today use two or more such propellers, and are powered by steam turbines (see page 532).

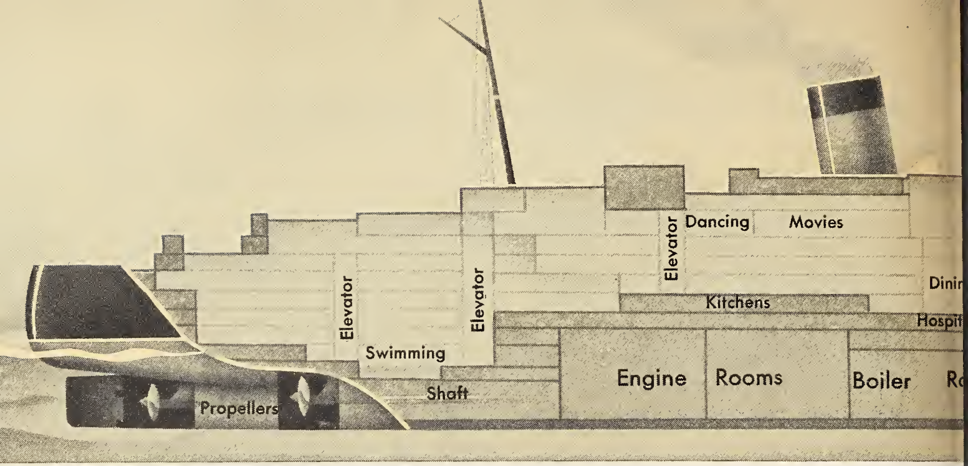
Diesel engines. The development of Diesel engines meant that ships could be operated with greater economy; and since Diesel engines take up less space, there was more room for cargo. For these reasons, Diesel-powered ships became popular and today carry more cargo than all other types combined.

Electric motors. Steam turbines may be used to power ships directly; they may also run electric generators which furnish electricity for motors that drive the propellers. This system of power has the added advantage of furnishing electricity for a great many other purposes.



On the left is the clipper ship *Sweepstakes* as she appeared in 1855. Note the large amount of sail used on these ships. On the right is an American steamship used in 1874. Note the paddle wheel used to drive it through the water.

New York Public Library



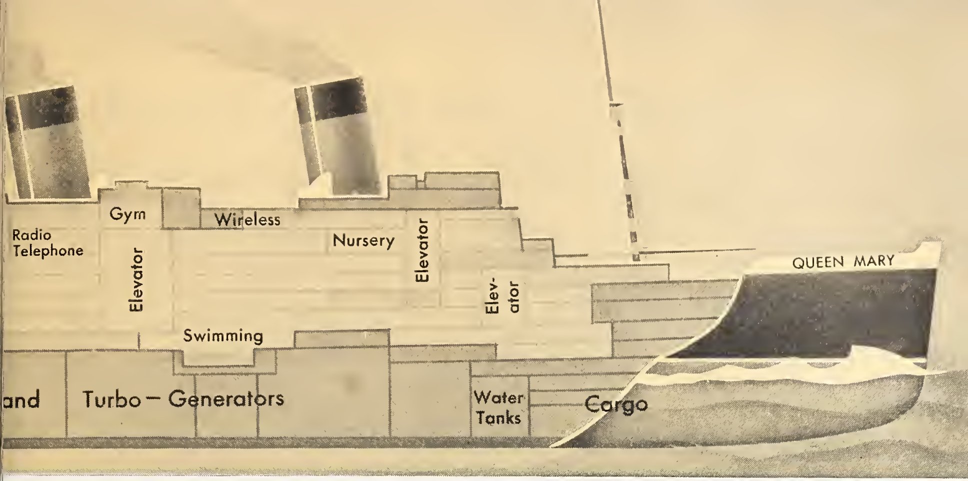
The *Queen Mary* is 1020 feet long, about 3½ times as long as a football field. A trip around the 3 acres of deck is about ¼ mile. Twenty-one elevators transport cargo and passengers between her 12 decks. Most of the passenger rooms have private baths, telephones, and air-conditioners. The large dining room seats 800.

VARIETIES OF SHIPS

Passenger ships. Of all the ships at sea, the passenger ships are the most luxurious. Large and fast, they are equipped with all kinds of scientific devices to make travel comfortable. The power requirements of a ship the size of the *Queen Mary,* one of the largest passenger ships, are tremendous. Power is required to turn four huge propellers, each 20 feet across and weighing 35 tons. They drive her through the water at an average speed of 30 knots, or 30 nautical miles, per hour (one nautical mile is 1.14 times an ordinary mile). Electricity enough to supply a small city is necessary for several thousand light bulbs and hundreds of devices used by the passengers, as well as for navigation instruments, communication equipment, fire apparatus, and cooking and cleaning appliances. To meet all these requirements, the ship has seven generators that furnish a total of 9,000 kilowatts of power. The distribution and control of this power requires two switchboards, one 37 feet long, the other 46 feet long, with hundreds of switches, meters, and controls.

The 140-ton rudder used to steer the ship is operated by machines with finger-tip controls. A large *gyrocompass,* which contains a small gyroscope indicates by its axle the direction of the course at all times, and can be connected with the machine operating the rudder for automatic steering. To aid in navigation when visibility is poor, the ship is also equipped with radar.

Cargo ships. Many different types of *cargo ships,* ships that carry freight, are in use, each designed for special cargoes. Ships on the Great Lakes, for example, that carry wheat and ore are little more than floating containers built like a steel box, 500 feet long, 65 feet wide, and 30 feet deep. A bow and stern have been added so that the



Time drawing by R. M. Chapin, Jr., courtesy of Time, copyright Time, Inc., 1947

The athletic facilities include a swimming pool, a fully equipped gymnasium, and several kinds of playing courts. There is a ballroom, library, writing room, children's playroom, and Turkish baths. The approximate location of a number of these facilities, as well as other parts of the ship, is shown in the above cross-section.

ships can be sailed. They are fast and can be loaded and unloaded speedily. On one occasion, it took only 16½ minutes to load 12,508 tons of iron ore on one of these ships.

Long, low ships to transport oil, called *tankers,* are little more than steel tanks. They carry about 15,000 tons of oil, and travel 15 knots an hour. Other cargo ships are built to carry great weight. One such ship carried a load of 20 large locomotives, 24 electric passenger cars, 2 small river tugs, and another cargo ship over 90 feet long weighing 100 tons. Still other types of cargo ships are three-deck freighters designed to carry livestock, refrigerator ships for perishable cargo such as fresh fruit, and nickel-lined ships for carrying corrosive materials such as lye.

Special-purpose ships. Where it is impossible to build lighthouses, a *lightship* is anchored to warn of hidden reefs or rocky shores along sea routes. Built with bulging sides and high prows, the lightship can ride the high seas in a storm. It is equipped with several kinds of warning devices: a beacon light on the highest point, a foghorn powerful enough to be heard about 14 miles, and a radio beacon that sends signals over and over again. The radio beacon is synchronized with the foghorn so that by measuring the time interval between receiving the radio signal and hearing the foghorn, the captain of a ship can estimate rather closely his distance from the lightship. A submarine bell also sends warning signals that travel at a speed of about 4,800 per feet per second, which can also be used to estimate distance to a lightship.

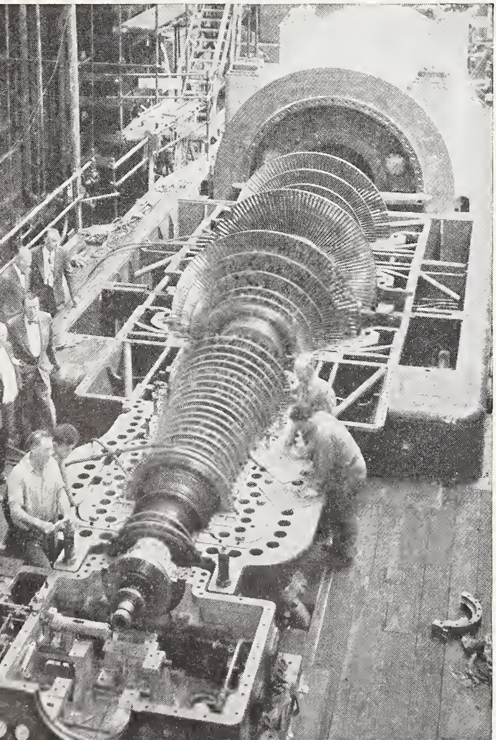
Another protection for ships is the floating signal called a *buoy*. Some of these are 40 feet long and weigh 12 tons. They are equipped with lights, bells, or whistles. To keep these buoys working and in their proper place, ships called *lighthouse tenders* are operated. *Cable ships* keep in repair telephone cables laid on the bottom of the ocean. Around the docks small but powerful *fireboats* protect ships from fires (see left). The real "work horse" of the harbor is the *tugboat,* which guides large ocean liners into the piers, and tows oil barges, sand and coal scows, and dredges.

New York Fire Department

A fireboat in New York City harbor. One such boat travels faster than 16 knots and can throw 20,000 gallons of water per minute with a pressure of 150 pounds per square inch.

A large steam turbine designed to drive an electric generator. Steam acts against the vanes, clearly visible in the picture, causing the turbine to rotate rapidly.

General Electric Company



SUMMARY

A great variety of ships have been designed to carry on the water transportation of the world. These range from the large, fast ocean liners to the small, powerful tugboats. Each performs efficiently an important function in water transportation, aided by many scientific devices.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words which should be substituted for the italicized ones to make the statement true.

1. A nautical mile is *1.14* times an ordinary mile.
2. Many ships are equipped with a navigational aid called a *gyrocompass* which is especially useful when visibility is poor.
3. A ship used to haul oil is called a *tanker*.
4. A ship used to give warnings during storms is known as a *lighthouse*.
5. The *cable ship* is often called the "work horse" of the harbor.
6. The first steamships were driven by *screw propellers*.

PROBLEM 3. How are aircraft used in transportation?

TYPES OF AIRCRAFT

Two main types of aircraft have been developed. One type, lighter than air, is known as an *airship*. Man's first flights into the air were made in them. The other type is heavier than air and is known as an *airplane*. More recently developed than airships, airplanes are much more widely used today.

Early attempts at flight. Man has always wanted to free himself from the earth and fly through the air. As early as 1250, an English scientist, Sir Roger Bacon, suggested that a hollow globe filled with a light substance could be made to float in the air; but not till 1783 was the idea demonstrated to be practical when two Frenchmen, Joseph and Jacques Montgolfier, flew a paper balloon filled with smoke and heated air to a height of 1,000 feet. Later that same year, a balloon filled with hydrogen was released in Paris and disappeared in the clouds. When it came to earth about an hour later some fifteen miles away, the people who saw it thought it was a huge monster from another world and armed themselves against it with pitchforks and muskets, and finally shot it. When the gas leaked out, it collapsed, and the people wildly celebrated their victory.

Lifting force of balloons. The buoyancy of air makes it possible for balloons to exert an upward force. In air, a balloon is lifted upward with a force equal to the total weight of the air it pushes aside. Some large balloons have a capacity of about 500,000 cubic feet. Filled with hydrogen, they can lift approximately .017 pound for each cubic foot of their capacity, or about 8500 pounds.

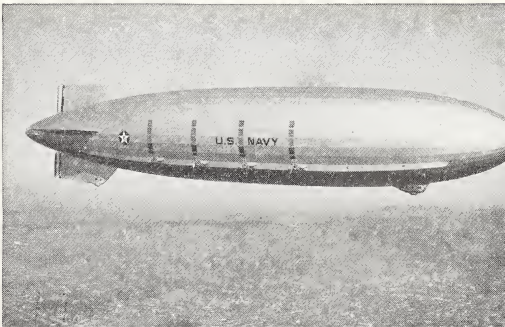
A balloon filled with hydrogen gas will lift the largest possible load, but hydrogen is inflammable and great precautions must be taken to prevent a fire when it is used. Another gas, helium, although it is heavier than hydrogen, is often used because it will not burn; the extra lifting force of hydrogen is sacrificed for the additional safety of helium. Because they are at the mercy of air currents, balloons are not satisfactory for transporting freight or passengers. They are used for special work, however, by the weather bureau and for high altitude research (see page 286).

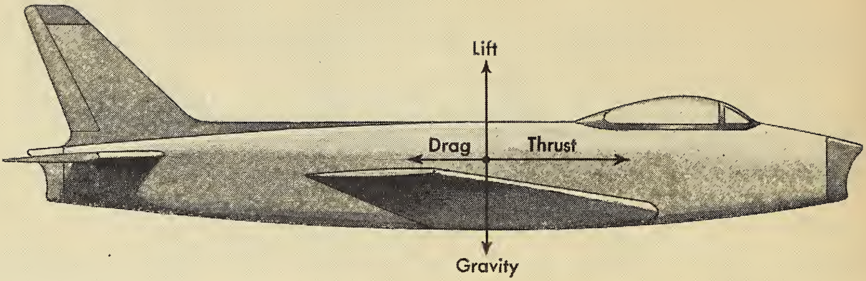
Dirigibles. When engines with propellers are added to drive the airship, and elevators and rudders to guide it, the resulting airship is a *dirigible*.

Dirigibles with no internal framework, called *nonrigid* dirigibles, are supported only by gas pressure. They have been widely used for observational work by the armed forces. Their chief advantage is that when the gas is

The dirigible *Macon* as she appeared in 1933. Although several countries have built large rigid dirigibles, most of them, including the *Macon,* have been destroyed as a result of accidents.

U.S. Air Force





The four forces act as though they were centered at one point in the airplane called the center of gravity. In the above diagram, since lift and weight are equal, the airplane will not rise or fall. But thrust exceeds drag, so the airplane will move forward.

removed, they can be packed into a small space for transportation.

Another type of dirigible has a metal frame beneath it from which passenger compartments and engines are suspended. Such semirigid dirigibles are used for passenger service and for advertising purposes. *Rigid dirigibles* with a 7,000,000 cubic-foot gas capacity have also been built (see page 533).

HOW AIRPLANES FLY

An airplane in flight is acted upon by two sets of opposing forces; *lift vs. gravity,* and *thrust vs. drag*. The relationship of these forces in level flight is shown on page 43.

Lift vs. gravity. Lift results from a combination of two forces developed as air rushes past the wing of the plane (see above). With any particular wing design, the greater the number of air molecules that move past the wing, the greater the lift. Thus both the density of the air and the speed of the air molecules past the wing affect the lift. Pilots always try to take off and land against the wind to get the greatest possible lift at the slowest possible airplane speed.

Gravity constantly pulls the airplane and its load toward the center of the earth. This pull is commonly expressed as weight. To make an airplane take off or remain in the air, the lift must be greater than the weight.

Thrust vs. drag. The force which drives an airplane forward is called *thrust*. In some airplanes thrust is produced by motor-driven propellers. The propellers have curved blades so designed that as they turn they act as screws and pull or push the plane forward. In other airplanes, the thrust is developed by high-speed jets of hot gases (see page 541). Sometimes rockets are added to propeller-driven airplanes to be fired when additional thrust is needed for extra speed or lift (see page 541).

The thrust of an airplane is at all times opposed by the resistance of the air to the movement of the airplane through it. The force resulting from air resistance is called *drag*. Since drag is the force that holds back an airplane, designers are constantly trying to reduce it.

Shaping the airplane surfaces so that they move through the air as smoothly as possible is known as *streamlining*. The effect of streamlining on drag is shown below.

Drag can also be reduced by making the airplane surfaces as smooth as possible. Rivets used in the construction of the airplane are concealed so that the rivet heads do not offer resistance to air flow. Special finishes also help reduce drag.

Guiding airplanes. An airplane has a number of movable surfaces, as shown on page 536. When one of these surfaces is moved so that it is no longer in line with the rest of the surface near it, the air striking it develops a force which the pilot can use to control the airplane. Thus if the elevators are lowered, the air stream pushes them, and the tail, up. The nose then drops, and the airplane flies along a descending path.

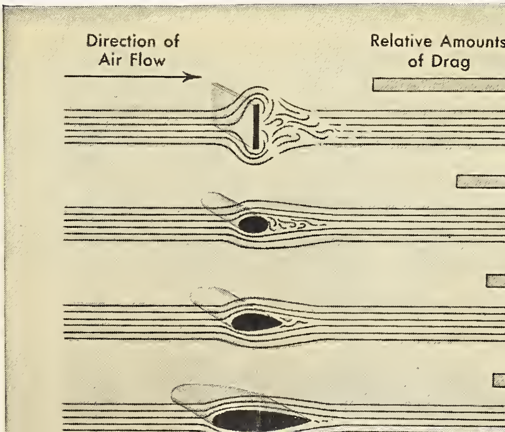
Airplane engines. The development of powerful, dependable airplane engines has been largely responsible for the rapid progress made in fast, safe air transportation. The basic principles of operation of four types of widely used airplane engines are shown on page 537.

Supersonic flight. If, on a clear day, you should hear two quick, loud claps like thunder, followed by a somewhat diminished roar, it would probably be an airplane breaking through the sonic barrier into supersonic flight. (*Super* means above, and *sonic* means sound.)

The sonic barrier. When an airplane travels more slowly than sound, it produces air waves that travel ahead of it. These waves seem to prepare its way, so that the air slides over and under the wing surface with a minimum of disturbance. As the airplane reaches the speed of sound, its waves are no longer effective because the airplane is traveling as fast as they are. Air seems to pile up, swirl, and break unevenly over the airplane. At the speed of sound, the forces from the swirling air are so great that the controls no longer work as they should, the airplane vibrates and shakes all over as though it were being pounded by hundreds of invisible hammers. Many of the first airplanes to reach the speed of sound were literally torn apart by these tremendous forces. Because of the above effects, the speed of sound is known as the *sonic barrier*. Moving through it safely is one of the problems faced in supersonic flight.

Mach number. Since the speed of sound is such an important factor in supersonic flying, it is important for a pilot to compare his speed with that of sound at all times. However, the speed of sound is not the same at all

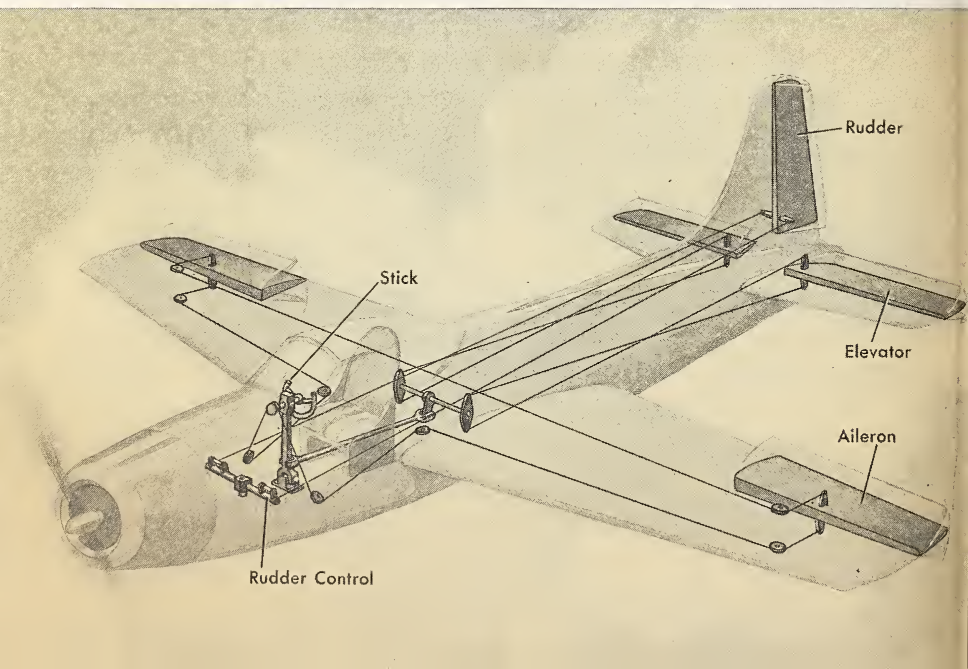
The air offers resistance (drag) against any object moving through it. The shape of an object affects the drag, as shown here. Shaping objects to reduce drag is known as streamlining.

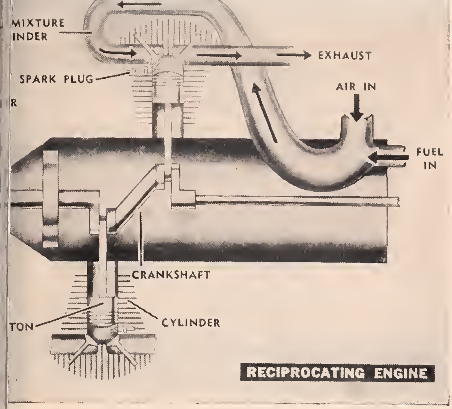


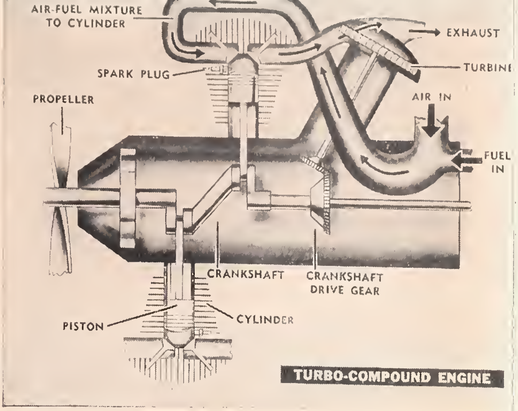
altitudes, since both temperature and density of air affect it. For example, at sea level at a temperature of 59°F, the speed of sound is about 761 miles per hour. At 35,000 feet, where the air density is less and the temperature is about −65°F, the speed of sound is only about 660 miles per hour. So speed in miles per hour will not tell a pilot how near he is to the sonic barrier. For this reason, airplane speed is rated in a unit called the *Mach* in honor of a German scientist, Professor Ernst Mach, who was one of the pioneers in the study of supersonic speed. The speed in Machs is found by dividing the speed of sound at the plane's altitude by the plane's speed in miles per hour. Thus the sonic barrier is always Mach 1. Other Mach ratings are shown on page 538.

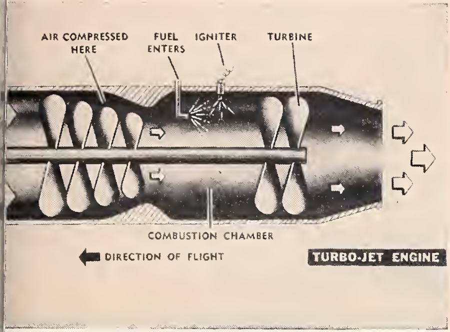
Strangely enough, heat rather than cold creates a major problem in supersonic flight even when the outside temperature is −65° F. The heat comes from the friction of the air passing over the airplane surfaces. At Mach 3 the temperature may rise 600° F, while at Mach 5 it may rise as much as 1600° F. At such high temperatures, the metals ordinarily used in airplanes soften and lose their strength. At higher speeds, the airplane might even burn up. Remember it is friction that causes meteors to become "shooting stars" (see page 111). Airplane designers must solve this problem before flight at such speed is practical. The cockpit of the experimental airplane which has flown as fast as Mach 2.5 is cooled by a refrigeration system which could cool a theater seating 3000 to 4000 people.

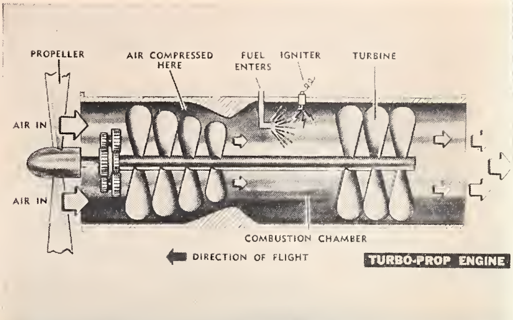
An airplane has a number of movable surfaces that are used to guide it. The various control surfaces together with their names are shown above. When these surfaces are moved properly, the air striking them develops forces that will turn the airplane or cause it to climb or descend as desired.







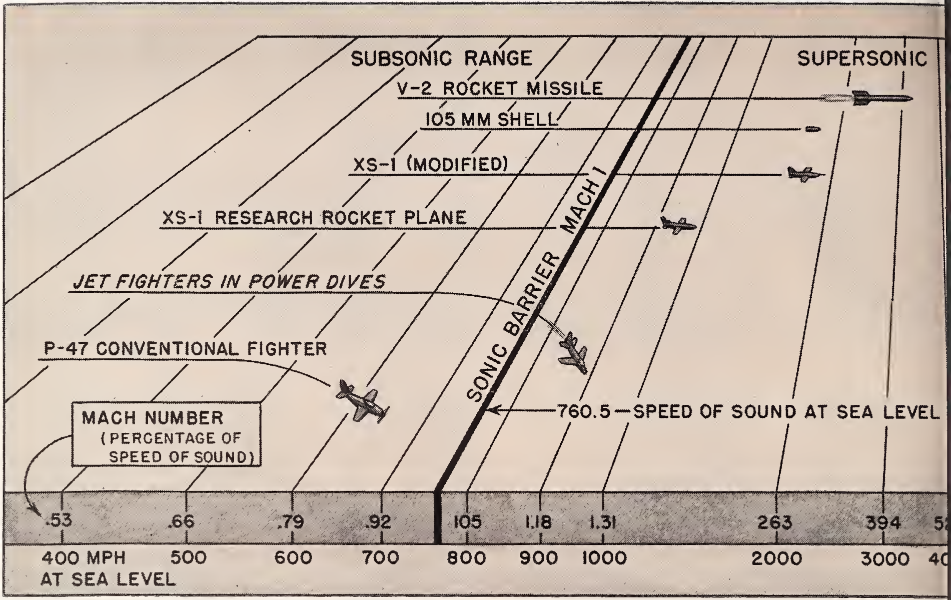




Curtiss-Wright Corp.

The two top engines are four-stroke cycle type. The original Wright engine weighed 179 pounds and developed 12 horsepower, about 15 pounds per horsepower. Modern reciprocating engines develop 3500 horsepower and weigh less than 1 pound per horsepower. They can operate as much as 2000 hours between overhauls. They waste the most power in the form of hot gases blowing out the exhaust. By placing a turbine in the exhaust and adding its power to that of the engine, turbo-compound engines develop 20% more power from the same amount of fuel. The large Douglas DC-7's and Lockheed Super Constellations are powered with turbo-compound engines.

The turbo-jet is the most powerful engine used on regular airplanes. It operates most efficiently at high altitudes because the exhaust gas can escape with least interference there by increasing the thrust. Airplanes making supersonic flights are powered largely by turbo-jet engines. Combining the turbo-jet with a propeller gives the turbo-prop engine almost twice as much power as the turbo-compound engine. The turbo-prop weighs only about ½ pound per horsepower. Although not so powerful as the turbo-jet, its fuel consumption is less, making it more adaptable to long-distance flying.



The relationship of miles per hour and Mach numbers is at sea level only. At high altitudes the speed of sound is still Mach 1 but the speed in miles per hour is less than at sea level. The speed of the objects in flight is in approximate Mach numbers rather than miles per hour.

Wind tunnels. Scientists learn much about supersonic flight by studying the action of models suspended in a stream of air moving at supersonic speed. The device for producing such an air stream is known as a *wind tunnel.* Some of these tunnels enable models to be studied at speeds as high as Mach 10. Wind tunnel studies have shown why thin wing sections are desirable for supersonic flight (see page 535 and picture on page 515).

Passenger airplanes. The trend in passenger airplane design is toward larger, faster, and more comfortable airplanes. In this field, as well as in the military field, the newest, fastest airplanes are jet-powered. One of these is shown in the picture at the right on page 540.

Helicopters. Helicopters can rise vertically, hover over some spot, and descend vertically. In an ordinary airplane, the wings are attached to the body of the airplane; therefore, the entire machine must move through the air to create lift. In the helicopter, the wings are in the form of a fan above the body of the machine. The engine rotates the wings thus moving the air past them fast enough to create the required lift. By adjustment of the wings, it is possible to fly forward, backward, or to either side. Although helicopters cannot fly at high speeds, they are widely used for flights where ordinary landing fields do not exist.

Modern airports. Airports are an essential part of a good air-transportation system. An airport includes a landing field on level land and the buildings needed to house the equipment and personnel required to keep the airplanes flying. These include a weather station to gather data essential to the pilots, radios for communication with pilots flying within range, and a traffic tower to control the movements of airplanes using the airport. The administration building also houses lounges, waiting rooms for the passengers, restaurants, ticket offices, and telephone and telegraph facilities. Near the landing field at large modern airports are equipment and personnel to make almost any kind of repair or adjustment that an airplane may need.

SUMMARY

Man's first successful attempts to travel by air were made in airships supported by the buoyancy of air. Although airships were found to be useful for some types of work, they have not been sufficiently dependable for general air transportation.

Because of its speed, dependability, and load-carrying capacity, the airplane has become the most practical means of air transportation. The modern airplane has been made possible through the use of science to solve the many problems involved in constructing airplanes that can fly efficiently at high speed.

OBSERVATION

What to observe. The action of one of the forces which lifts an airplane.

How to observe it. Hold to your mouth one end of a narrow strip of paper about 12 inches long, and blow across the top of the paper. Observe the action of the paper.

Interpretation of your observation. Write one sentence stating how one of the forces that lifts an airplane is produced.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Helium is used in balloons and dirigibles in the United States because (a) it is lighter than hydrogen; (b) it is more plentiful than hydrogen; (c) hydrogen slowly unites with oxygen to form water; (d) it will not burn.
2. Gasoline engines used in some modern airplanes weigh (a) 50 pounds per horsepower; (b) 12 pounds per horsepower; (c) 500 pounds per horsepower; (d) less than one pound per horsepower.
3. The force which drives an airplane forward is known as (a) lift; (b) thrust; (c) drag; (d) gravity.
4. The type of airplane engine that uses both a propeller and a jet is the (a) reciprocating; (b) turbojet; (c) turbo-compound; (d) turbo-prop.

Wide World

Boeing Photo

Helicopters can be used in unusual rescue operations. The man at left being rescued is a chimney inspector whose ladder broke as he reached the top of a 150-foot smoke stack. The 707 at right will carry 100 passengers. It has 4 jet engines, a maximum speed of 600 mph, and a cruising speed of 580 mph.

CHAPTER ACTIVITIES

REVIEW YOUR UNDERSTANDING

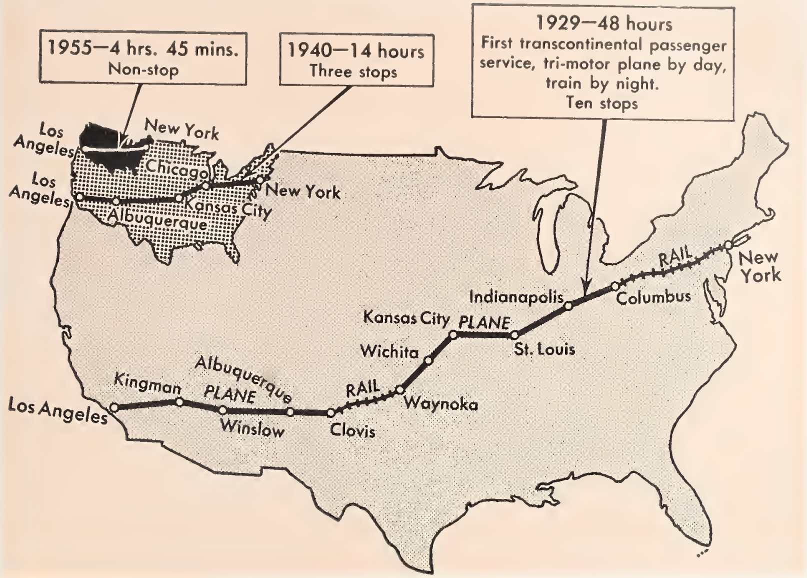
Three important generalizations developed in this chapter are listed below. Following each is a list of statements which may or may not illustrate the generalization. On your answer sheet, write the letters of those statements which illustrate the generalization under which they are listed. **Do not write in your textbook.**

1. Fast, safe railroad transportation has been achieved through man's use of science.

   a. The first railroad in the United States was built in 1826.
   b. The outside rail on curves is higher than the inside rail.
   c. Defective rails are located with a special rail inspection car.
   d. Some trains are automatically stopped if they enter a block of railway that is already occupied.
   e. A rise of one foot in each 100 feet of railway is called a 1 per cent grade.

2. Modern airplanes which fly at high speeds and altitudes are made possible through the use of science in solving many problems involved in their construction.

   a. Airplanes that fly at supersonic speed contain a refrigeration system.



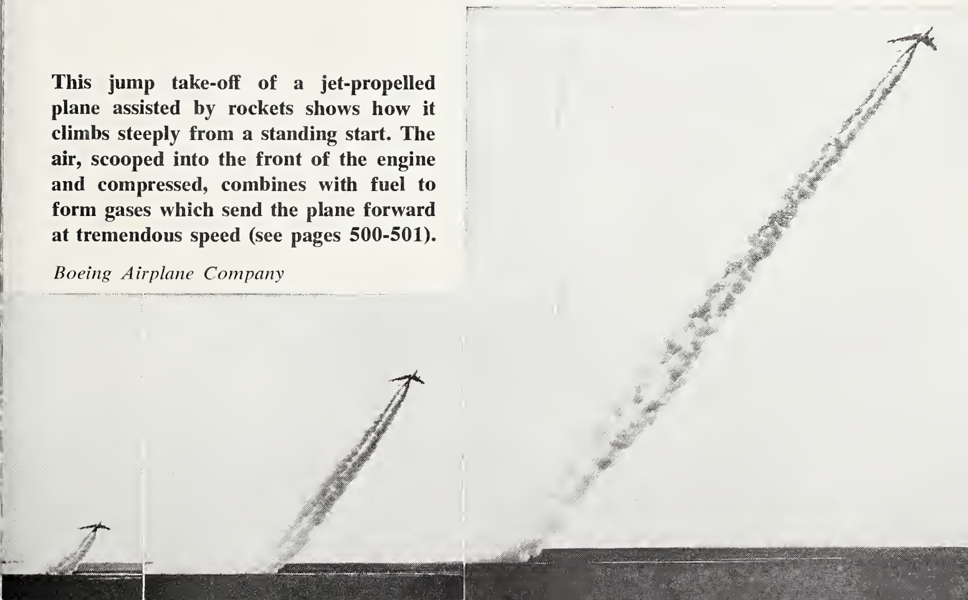
The development of fast, dependable air transportation has shrunk distance until many people give the distance between cities in time rather than miles.

b. The use of strong, lightweight metals has made it possible to build engines which weigh less than one pound per horsepower.

c. The speed of sound is called the sonic barrier.

d. Airplane wings provide a maximum lift with a minimum of drag.

e. A turbine in the exhaust of a reciprocating engine increases the power of the engine about 20 per cent.



This jump take-off of a jet-propelled plane assisted by rockets shows how it climbs steeply from a standing start. The air, scooped into the front of the engine and compressed, combines with fuel to form gases which send the plane forward at tremendous speed (see pages 500-501).

Boeing Airplane Company

N.B.C. Photo

The interior of this radio studio is designed so that programs broadcast from it will sound as natural as possible.

chapter 28 SOUND IN COMMUNICATION

PROBABLY the most universal method of communicating with others is by sound. Early in life we learn to make sounds, then form them into words, and finally into sentences which express our thoughts. Not only do we speak with each other, but we also play or listen to music which is a blending of sounds, often written to express the composer's feelings to those who listen to his music. Then there is the sound of the automobile horn warning the pedestrian of danger; the many and varied sounds of the busy city; and the sounds of the quiet countryside. Man lives in a world filled with a variety of sounds, all of which affect him in one way or another. This chapter will help you understand how sounds are produced and how we use sound in communicating with others.

PROBLEM 1. How do we produce sound?

VIBRATIONS, TONE, AND PITCH

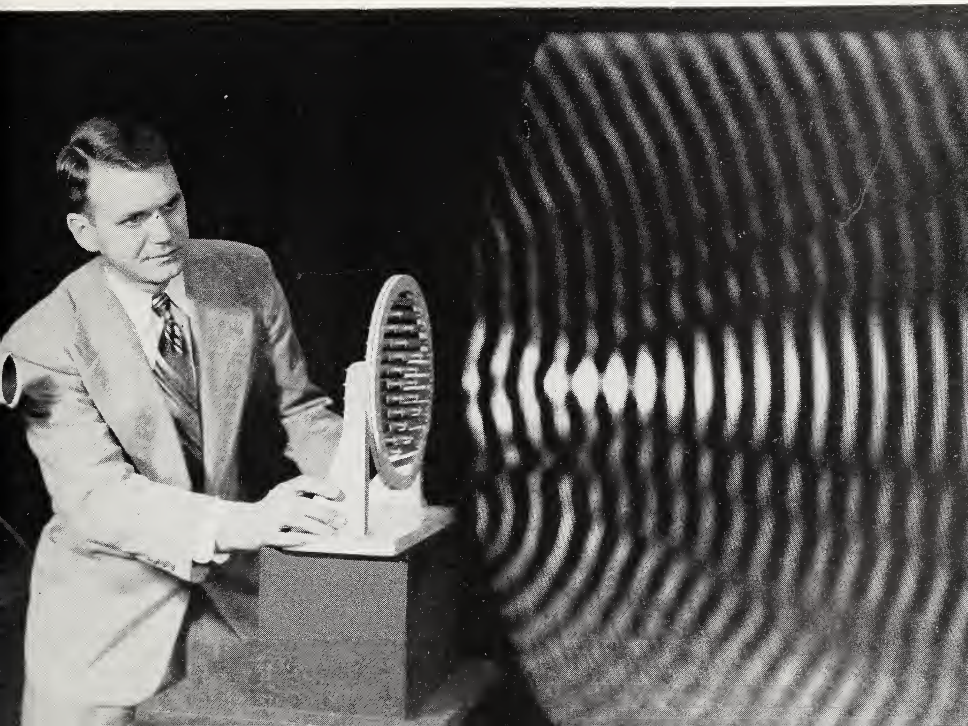
Vibration, source of sound. If you place your finger on the Adam's apple in your throat while you talk, you can feel something moving. If you place a finger next to a violin string while the instrument is being played, you can feel the strings move back and forth very rapidly. This back and forth motion in throat and in violin strings is called *vibration*. The number of times any object vibrates each second is its frequency.

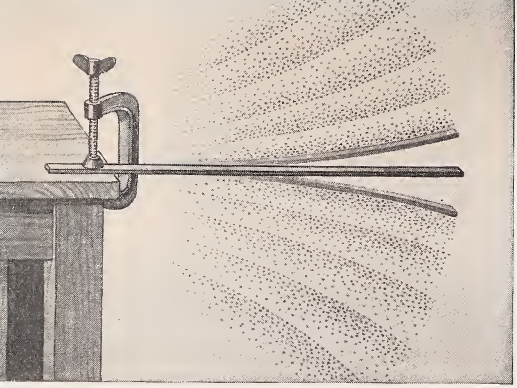
A vibrating object produces areas of alternating high and low air pressures which follow each other in rapid succession (see page 544). These pressure areas travel away from the object in every direction through the air. If an object vibrates at any frequency between 16 and 20,000 times per second, its vibrations will affect the average human ear so that sound is heard. A person cannot wave his arms fast enough to produce sound, although bees can move their wings so rapidly that a buzzing sound is heard when they are flying.

When an electric bell is operated within a jar containing air, the sound can be heard easily. If the air is removed from the jar, the sound of the bell gets weaker and weaker, until

A photograph of the pattern of sound waves. The wave is scanned by equipment consisting of a tiny microscope and a neon lamp. The pattern shown was made in a ten-minute period.

Bell Telephone Laboratories, Inc.





When a meter stick is vibrated, series of air waves are formed, each made up of high and low air pressure areas, as indicated by the dots.

finally it can scarcely be heard. Yet the bell can be seen to be operating as vigorously as ever. If all of the air could be removed from the jar, there would be no sound from the bell. There can be no sound in a vacuum because there is nothing around the vibrating object through which the waves can travel to reach a person's ear. Herein lies one striking difference between sound and radiant energy. The waves that cause sound must travel through some material but, as you remember, radiant energy can travel through an absolute vacuum.

Ultrasonic vibrations. When vibrations occur too rapidly for the human ear to hear, they are called *ultrasonic vibrations*. (*Ultra* means beyond, and *sonic means sound*.) The so-called silent dog whistle produces ultrasonic vibrations which a person cannot hear; but a dog, who can hear 40,000 vibrations per second, can hear the whistle and can be trained to come whenever it is blown.

Ultrasonic vibrations are used in many ways. Some dairies use them to kill the bacteria in milk and to break up the milk fat into minute particles. Milk so treated will remain fresh longer and is more digestible than untreated milk. Ultrasonic vibrations are used in controlling smoke and collecting soot from industrial power plants. They are also used in clearing fogs. Paints, mayonnaise, and face creams can be mixed more evenly by using ultrasonic vibrations.

Musical tones and noise. Most of the sounds we hear are the result of a number of vibrations, each occurring at a different frequency. Sounds can be considered as either *musical tones* or *noise*. Even though a sound results from vibrations occurring at different rates if they follow each other in a regular, definite order, the sound has a pleasing effect, and is called a musical tone. The sounds produced by musical instruments, singers, and birds are considered musical tones. On the other hand, if the sound results from vibrations occurring at different rates but without any definite order, the sound is not pleasing and is called noise. Noises, such as those heard when an object is dropped, a sheet of paper is crumpled, and a pane of glass is broken, are produced by an irregular order of vibrations.

Pitch of sounds. The shrill whistle of the referee at a basketball game can generally be heard above the noise of the crowd because the frequency of vibrations produced by the referee's whistle is much higher than those produced by the crowd. The *pitch* of a sound is determined primarily by its frequency. Rapid frequencies produce sounds of high pitch, while slow frequencies produce sounds of low pitch.

Quality from overtones. Sounds also have an additional characteristic, that of *quality*. The characteristic quality of

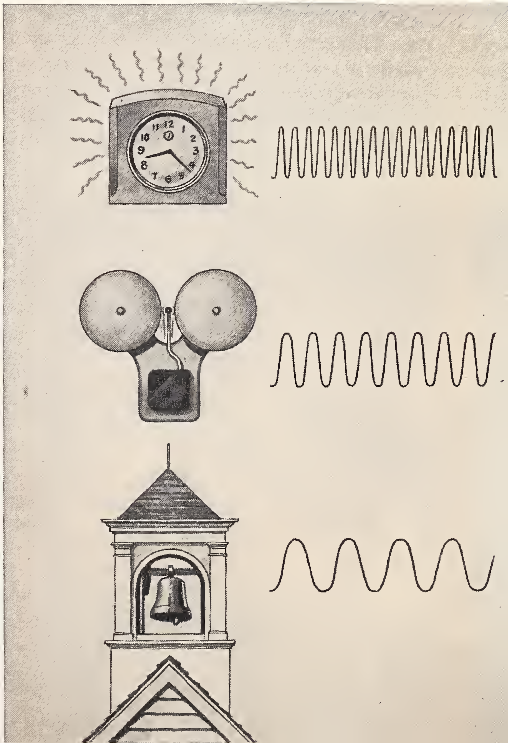
DISTRIBUTION OF OVERTONES AND PERCENTAGE OF SOUND CONTRIBUTED WHEN THREE INSTRUMENTS PLAY THE SAME TONE

INSTRUMENT	VIOLIN PER CENT	FLUTE PER CENT	FRENCH HORN PER CENT
Fundamental (Middle C)	60	13	2
Second overtone	8	40	10
Third overtone	20	10	50
Fourth overtone	10	20	15
Fifth overtone	2	5	5
Other overtones	0	12	18
Total	100	100	100

a tone from a musical instrument enables us to tell by the sound alone what instrument is producing it. A single frequency determines the pitch of the tone. This frequency is called the *fundamental.* But few tones contain only a single frequency. They contain a number of frequencies higher than the fundamental. These are called *overtones.* Notice the difference in pattern of overtones shown in the table above. It is the pattern of overtones which gives a tone its characteristic quality. Without the overtones and the amount of sound they produce, it would not be possible to tell one musical instrument from another when they were playing the same fundamental. Singers spend much time in learning to control the overtones of their voices so that they will be pleasing to hear. Speech training is also planned to help the speaker use his voice so that it is distinctive and pleasing.

Volume and amplitude. Some sounds are so faint that they can scarcely be heard. The gentle rustle of the breeze through the trees is such a sound. Others, like the crash of thunder, are so loud as to be almost deafening. The loudness, also called *volume,* of any sound depends upon the amount of motion given the air molecules by the vibrating object. In faint sounds the air molecules are moved only slightly, but in loud sounds they are moved much more. In fact, the sound from an

A diagrammatic comparison of the frequency of sound waves of three different bells. The alarm clock bell produces a sound of highest frequency and therefore of highest pitch.



explosion may move the air molecules so much that they exert enough force to break windowpanes in a building. A measure of the distance the air molecules are moved is known as the amplitude of the sound wave. The loudness of sound is therefore dependent upon the amplitude of the sound waves; it is often measured in units called *decibels.* Sounds so faint that they can just be heard are given a decibel rating of zero. By such a system, the rustle of leaves has a decibel rating of about 9, ordinary conversation of about 56, an airplane engine of about 110, and thunder of about 118.[1]

Musical instruments. In violins, guitars, and cellos, the tones are produced by the vibrations of strings and the body of the instrument to which they are attached. In the clarinet, oboe, and saxophone, the tones are produced by a vibrating reed and a column of air inside the instrument. The musician plays the instrument by blowing air over a thin reed causing it to vibrate. In playing a cornet or trombone, the musician's lips serve the same purpose as the reed in the saxophone. Musical tones are obtained from the xylophone when wooden strips are struck, causing them to vibrate. The quality of the tone obtained from any musical instrument is affected greatly by the size, shape, and composition of the body of the instrument.

Producing tones of different pitch. If you examine the strings on a piano, you will find them to be of different sizes and lengths. The pitch of the tone produced by any string can be varied by changing the tightness with which the string is stretched. This is what the piano tuner does to obtain the desired pitch when he tunes a piano.

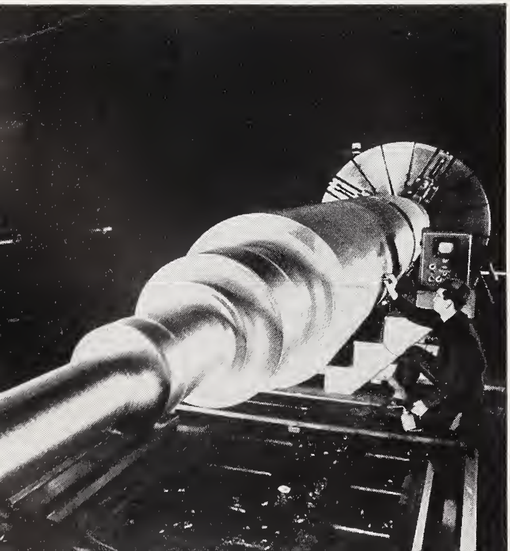
The violin is also tuned by tightening or loosening the strings. The length of the string is varied and different tones are produced when the violinist presses the strings at different positions with his fingers, as he moves the bow across them.

The different tones are produced in some musical instruments by changing the length of a vibrating air column. In instruments such as the flute and clarinet, the length of the vibrating air column is changed by covering and uncovering holes in the instrument. In others, such as the cornet, the length of the vibrating air column is changed by pushing down valves. The size of each wooden strip on a xylophone determines the pitch of the tone produced when it is struck.

Tuning musical instruments. When two tones of slightly different pitch are

Testing a steel forging with a sonic tester. The difference in the pulses of energy from weak spots is registered so that the defects can be quickly discovered.

U. S. Steel



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[1] Keith Henney, *Principles of Radio* (New York, John Wiley and Sons, Inc., 1942), p. 312.

Gregor from Monkmeyer

A variety of instruments used in an orchestra can be seen in this photograph. Each instrument produces its own characteristic tone determined by the number and relative strength of the overtones present in the sound.

played, the resulting sound is first loud and then soft at regular intervals. For example, if a tone of 250 cycles per second is played with one of 251 cycles per second, the sound will become loud and then soft once each second. Thus the tones, instead of blending together to produce a steady sound, seem to throb at a definite rate. Each throb is called a *beat*.

Musicians can tell when two instruments are in tune by listening for beats when they play tones of the same pitch. If none can be heard, the instruments are in tune. When musical instruments that are out of tune with each other are played together, they produce beats which make the music unpleasant to hear.

Sympathetic vibrations. Have you heard some object in the room make a humming noise while the radio is turned on? The humming noise is caused by the vibrations of the object. The object is sensitive to the frequency of some sounds in the music which, therefore, cause it to vibrate. Vibrations produced in this manner are called *sympathetic vibrations*.

Speed of vibrations. If you watch a steam locomotive from a distance at the time its whistle is blown, you will see a puff come from the whistle some time before you hear the whistle. The time interval between seeing the white puff and hearing the sound is accounted for by the fact that air vibrations travel

APPROXIMATE SPEED OF VIBRATIONS IN DIFFERENT SUBSTANCES AT 20°C.

SUBSTANCE	FEET PER SECOND
Air	1120
Hydrogen	4363
Water	4757
Brass	11,480
Granite	12,960
Maple wood	13,480
Iron	16,820
Glass	19,680

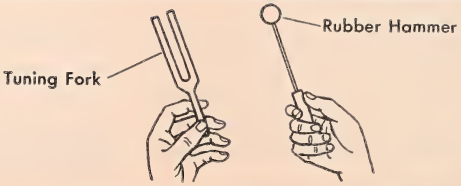
much more slowly than light. As you know, light travels about 186,000 miles per second. Many measurements have shown that air vibrations travel only 1,080 feet per second at sea level when the temperature is 0°C. When the temperature is raised above 0°C, they will travel faster. Ordinarily air vibrations travel at speeds ranging from 1,100 to 1,200 feet per second. Thus a train whistle one-half mile away would be heard in a little over two seconds.

Vibrations can also travel through many substances other than air. In fact, they travel more rapidly through most substances than through air, as shown in the table which appears in the column at left.

SUMMARY

Vibrating objects produce waves in the air surrounding them. Sound results from our responding to these waves. Since our ears are sensitive only to certain frequencies, not all vibrations produce sound. The nature of the vibrations reaching our ears makes it possible for us to identify sounds as to their pitch, quality, and loudness. Musical instruments can be used to produce sounds that are pleasing to hear.

OBSERVATION

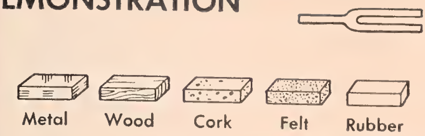


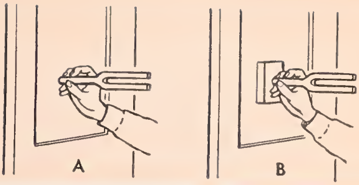
What to observe. A tuning fork as it produces sound.

How to observe it. Strike a tuning fork (preferably one of low pitch) with a rubber hammer or against the rubber heel of a shoe. Hold the tuning fork near the ear, then dip the ends of it into a beaker of water. Strike the tuning fork again, and touch it lightly to the tip of your tongue.

Interpretation of your observation. Write a generalization stating how a tuning fork produces sound.

DEMONSTRATION





Generalization to be demonstrated. Materials vary in their ability to carry sound.

What you need. A block of metal, a piece of wood, a cork, a felt pad, a sponge-rubber pad, all of the same thickness (from ¼ to ½ inch), and a tuning fork.

What to do. Strike the tuning fork, and touch its base to the panel of a door. Note the loudness of the sound. Now place each of the materials, one at a time, between the door and the base of the tuning fork after the ends of it have been struck. Strike the fork with the same force each time. Note the difference between the loudness of the sound in each case.

What to observe. Which materials transmit the sound of the tuning fork to the door with the least loss? Arrange the materials in order of their ability to conduct sound, ranging from those that are the best to those that are poorest.

What does it mean? How does the evidence obtained in this demonstration tend to prove or disprove the generalization at the beginning of the demonstration?

Basic assumptions in this demonstration. 1. The tuning fork was struck with the same force at the beginning of each trial and, therefore, its amplitude of vibration was the same.

2. What other assumption must you accept?

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The number of times a substance vibrates in each second is called (a) frequency; (b) amplitude; (c) speed, (d) loudness.
2. The fastest vibration of a substance which a person can hear is about (a) 5,000 per second; (b) 10,000 per second; (c) 20,000 per second; (d) 30,000 per second.
3. The pitch of a musical tone depends primarily upon its (a) amplitude; (b) frequency; (c) overtones; (d) speed.
4. The speed of sound in air is about (a) 20,000 feet per second; (b) 10,000 feet per second; (c) 5,000 feet per second; (d) 1,000 feet per second.

PROBLEM 2. How do we control sound for communication?

PRODUCING SPEECH SOUNDS

Sound in speaking. We are so accustomed to talking with other people that we seldom think of the difficulty we had in learning to talk. Yet if you observe a baby just learning to talk, you will soon see that forming words is a difficult process which is mastered only after much practice.

The sounds used in speaking are formed in the *larynx,* often called the Adam's apple or voice box. Inside the larynx are two strong tissues called *vocal cords* which vibrate to produce sound (see above). It is the vibration of the vocal cords that you feel when you touch your larynx as you talk.

Producing the sounds with the vocal cords is only one step in speaking. The sounds must be controlled so that letters and words are properly pronounced. Molding the sound from the vocal cords into speech is done by the lips, tongue, and teeth. Pronounce a few letters such as *t, s, o, v,* and *y,* and notice how you use your lips and tongue. Then pronounce the words *run, out, bat,* and *overcoat.* Note the difference in mouth movement when you pronounce letters and words. If speech is to be clear and distinct, it is necessary that the sounds be formed accurately. Proper control of breathing together with accurate formation of sounds by the lips, tongue, and teeth add to the effectiveness of communication because it is easier for a listener to understand what is being said. Furthermore, the quality of the voice is improved so that it is more pleasant to hear.

Differences in voices. Speech sounds include fundamental tones ranging in frequency from about 100 to 2,600 cycles per second. As in music, there are also a great many overtones in speech. The quality of a person's voice is determined by the number and strength of the overtones present. Thus one's voice is almost as characteristic of him as are his fingerprints.

Generally men's voices have a lower fundamental pitch than women's voices. The fundamental range for a bass singer is from about 80 to 300 cycles per second while that of a soprano is from about 250 to 850 cycles per second. Voice training, however, has made it possible for many people to extend the ranges of their voices in both directions. In spite of the difference in fundamental pitch between men's and women's voices, each can form speech sounds that are distinct when heard. For example, a bass voice might pronounce the *a* in *talk* with a fundamental somewhere around 600 cycles per second while the soprano voice would pronounce the same *a* with a fundamental pitch as high as 950 cycles per

FREQUENCIES OF SPEECH SOUNDS

SPEECH SOUND	FREQUENCY OF LOW VOICE	FREQUENCY OF HIGH VOICE
ū as in pool	400	800
u as in put	475	1000
ō as in tone	500	850
o as in ton	700	1150
a as in father	825	1200
a as in tap	750	1800
ā as in tape	550	2100
e as in ten	550	1900
ē as in steam	375	2400
er as in pert	500	1500
i as in tip	450	2200

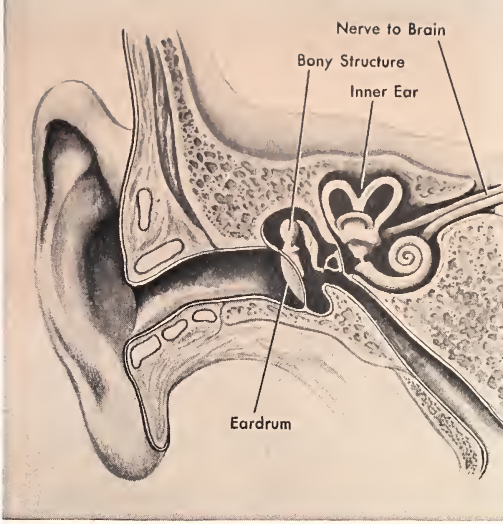
Table from Hausmann-Slack, *Physics,* D. Van Nostrand, 1939, page 563, as taken from work of Dr. Harvey Fletcher of Bell Telephone Laboratories.

second. The approximate low- and high-frequency ranges of some of the sounds are shown in the preceding table.

HEARING SOUND

The ear. We are all familiar with the fact that our ears receive the vibrations that result in sound. Yet we seldom realize what marvelous organs ears are. We can hear sounds so faint that the pressure of the air against the eardrum producing them is only about one twenty millionth of normal atmospheric pressure. On the other hand, vibrations must be large enough to produce a pressure ten trillion times as great as this before it becomes painful. Our ears also respond to the extremely complex vibrations of voice, music, and noise. Even though two complex sounds differ only in the number and strength of overtones present, we have little difficulty in distinguishing one from the other. The ability to distinguish between sounds of different quality adds to one's enjoyment of music.

The parts of the ear concerned with hearing are shown in the drawing at the right. As air vibrations strike the *eardrum,* they cause it to vibrate. A delicate bony structure carries these vibrations to the *inner ear,* which contains a spiral cavity shaped somewhat like a small snail shell and filled with a fluid. A membrane containing the nerve endings divides the spiral cavity into two halves except at its tip. When the vibrations reach the inner ear, they are carried throughout the fluid and cause the membrane to vibrate. Each part of the membrane seems to be sensitive to some particular frequency. Thus when a complex vibration of several frequencies enters the ear, the corresponding parts of the membrane vibrate at their particular frequency and send nerve impulses for that frequency to the brain, which interprets them as sound.



Parts of the human ear which make it possible to hear. When air vibrations hit the eardrum, small bones transmit vibrations to the inner ear where they cause nerve messages to be sent over a nerve leading to the brain.

Care of the ears. The ears are important organs and as such should receive proper care. One should never remove wax from the ear with a pointed object, since there is danger of damaging the eardrum. It is dangerous to shout loudly in someone's ear or hit him on the ears, for the sudden pressure change caused by a loud noise or a sharp blow may injure the eardrum. You should also avoid blowing the nose too hard when you have a cold, since the ear may become infected through the tube connecting the throat and the ear (see above). If you have ear trouble of any kind, it is wise to consult a doctor immediately.

People who travel by air may experience difficulty with their ears. The ears may "pop," feel as though they were stopped up, or even become painful, as the airplane climbs to higher altitudes or descends to land. These sensations are caused by a change in air pressure on the eardrum. The tube connecting the middle ear with the throat allows air to enter the middle ear so that the air pressure on both sides of the eardrum is the same. This makes it possible for the eardrum to vibrate freely. When the air pressure on the outside of the eardrum changes, as when you ascend or descend rapidly in an airplane, you may experience the sensations described above until the air pressure in the middle ear is made equal with that on the outside. There are several things you may do to help equalize air pressure on the eardrum. Yawning, chewing gum, and swallowing will aid in opening the tube so that the pressures can be equalized.

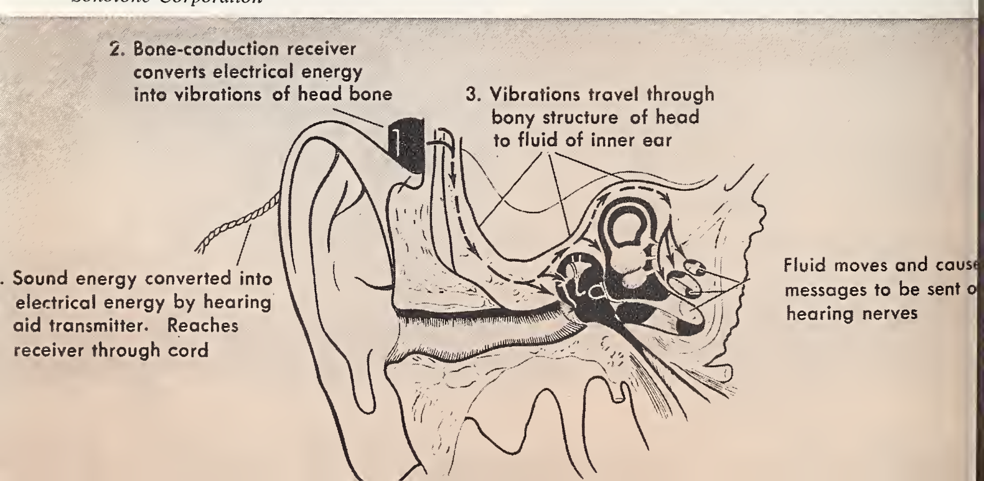
Aids for hard of hearing. Many people who cannot hear well can have their hearing improved with a hearing aid. In such devices the air vibrations strike a microphone and are reproduced in greater amplitude by a tiny earphone that fits into the ear. In some cases the vibrations are not sent into the ear channel, but are delivered directly to the bone behind the ear and travel through the bone to the inner ear.

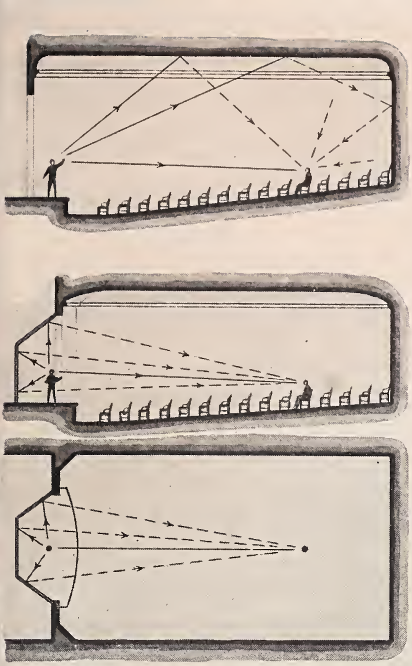
Reflection of vibrations. When air waves strike a smooth, hard surface, they are reflected from it with very little loss in strength. If you should stand about 110 feet from a cliff or large brick building and shout in the direction of the building, the vibrations will reach the building in about one tenth of a second. Some of them will be reflected from the building and start back toward you. Another one tenth of a second will be required for them to reach you. So you will hear your own voice a second time about one fifth of a second after you shouted. The second sound is an *echo*.

Reflected waves are always present

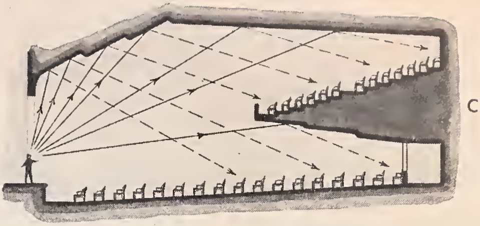
This type of hearing aid uses bone to conduct vibrations into the inner ear. In another type of hearing aid, the receiver is attached to the ear so that the strong air waves it produces cause the eardrum to vibrate in a normal manner.

Sonotone Corporation


2. Bone-conduction receiver converts electrical energy into vibrations of head bone
3. Vibrations travel through bony structure of head to fluid of inner ear
. Sound energy converted into electrical energy by hearing aid transmitter. Reaches receiver through cord
Fluid moves and caus messages to be sent o hearing nerves



Diagrams showing the effects of controlled and uncontrolled vibrations in an auditorium. In auditorium A the total vibrations received by any listener is made up of those coming direct and those reflected from ceiling or walls one or more times (dotted lines).



In auditorium B, properly placed reflecting walls at the sides and above the speaker amplify his voice by reflecting air vibrations. In auditorium C, the front portion of the ceiling is shaped so that every listener receives reflected vibrations following the direct ones closely enough to make them effective rather than distracting as in A.

when vibrations are made in a room with hard wall surfaces. However, if the room is small, the reflected vibrations reach your ear in such a short time that you cannot distinguish the sound they produce from the original sound. The original and reflected vibrations must reach your ear about one tenth of a second apart before you hear them as an echo. For an echo to be produced in a room, the walls must be about 55 feet from the source of the sound.

Auditoriums and theaters should be planned so that echoes are not present. Otherwise, the echoes interfere with both speech and music heard in the building. One way to prevent echoes is to cover the walls and ceiling with special materials that absorb the vibrations rather than reflect them. Draperies at the windows or over the wall surfaces also help absorb the vibrations. Architects plan large buildings so that no wall surfaces are in a position to reflect vibrations that will interfere with the hearing of the people in the building.

There are various means by which air vibrations can be directed toward listeners. For example, a cheer leader uses a megaphone when leading the cheering section. The sides of the megaphone direct the cheer leader's voice toward the people in the cheering section. A curved wall is often built back of a stage or a bandstand to reflect the vibrations toward the listener.

Limitations of sound in communication. Since air vibrations die out rapidly, direct communication by sound is generally limited to a few hundred yards. One exception to this is the yodel calls of the Austrian herdsmen in the Alps mountains. Reflected from the high mountain peaks and walls, these calls can be heard long distances through the valleys. By associating meanings with certain calls, they can communicate by voice for great distances in good weather.

Another limitation of sound for long-distance communication is the relatively slow speed at which air vibrations travel. Even if they could be beamed from one coast of the United States to the other, it would take about four hours for them to make the trip. Modern civilization demands more rapid communication than this. Electricity and radio waves have been used to overcome the limits of direct communication with sound.

SUMMARY

Sounds produced by air passing between the vocal cords are molded into speech used for communication. Essential to communication by sound is the ear, a complex organ which needs proper care. Communication by sound is most effective in properly designed buildings. Sound is not suitable for direct communication over long distances.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words which should be substituted for the italicized ones to make the statement true.

1. The quality of a person's voice is determined by the number and strength of the *overtones* present.
2. Men's voices generally have a *higher* fundamental pitch than women's voices.
3. An object must be at least *110* feet from a source of sound before it will produce an echo.
4. One method of preventing echoes in a large building is to cover the walls and ceiling with a material that *reflects* air vibrations.

CHAPTER ACTIVITIES

REVIEW YOUR UNDERSTANDING

In the following paragraph about sound, certain words have been italicized and numbered. Beneath the paragraph is a list of meanings. Select a meaning for each numbered word in the paragraph, and write its number beside the number of the word in the proper place on your answer sheet. **Do not write in your textbook.**

Sound[1] is probably our most important means of *communication*[2]. All sound is produced by some form of *matter*[3] which is *vibrating*[4] and in turn sets up *waves*[5] in the air which *surrounds*[6] it. Some vibrations produce *musical tones*[7] while others produce only *noise*[8]. Air vibrations do not travel with nearly the *velocity*[9] with which light travels, their speed being only *approximately*[10] one fifth of a mile per second.

We often hear an *echo*[11] in mountainous country or in large buildings where *sound treatment*[12] has not been provided.

MEANINGS

1. Covering the walls and ceiling of a room with materials which absorb air vibrations
2. Encloses, encircles, or goes completely around
3. Moving rapidly back and forth
4. Sound from a reflected vibration which can be distinguished from the sound produced by the original vibration
5. Loudness
6. Almost but not exactly
7. Rate of motion or speed
8. Sounds resulting from vibrations that follow each other in a regular, orderly way
9. Anything which occupies space
10. Areas of high and low air pressure which follow each other rapidly
11. Disturbances in air which may be received by ear and interpreted by brain
12. Sounds resulting from vibrations that follow no regular, orderly pattern
13. The act of giving information

USE THE FACTS FROM A TABLE

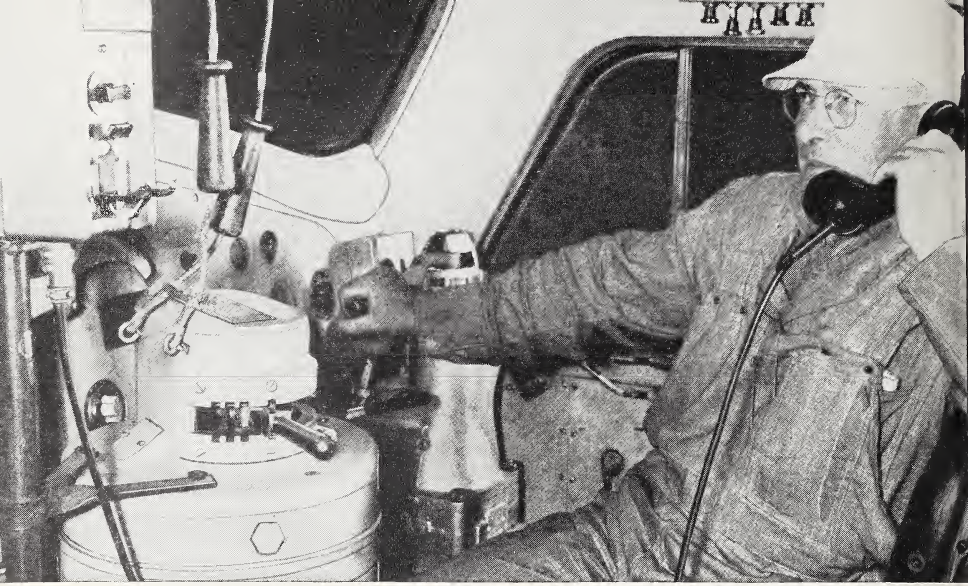
Each of the problems below can be solved by using facts given in the table on page 548. In each problem the temperature of the substance conducting the vibrations is 20°C. Each problem is followed by four possible answers. In the proper place on your answer sheet, write the letter of the answer which is most nearly correct.

1. Imagine that you are observing a football game at a distance of 100 yards from the referee. How long will it be before you hear the whistle blown by the referee?

a. ¼ second c. ⅓ second
b. 2 seconds d. 1 second

2. If a train were starting up one mile from the station, how long would it take before the vibrations from its wheels would travel through the rails to the station?

a. 1 second c. ⅓ second
b. ½ second d. 3 seconds



Association of American Railroads

Safe, dependable transportation is aided by radio telephone communication between engineers on moving trains and dispatchers and agents at wayside stations.

chapter 29 ELECTRICITY IN COMMUNICATION

IN the search for rapid, long distance communication, scientists turned to electricity. First they used electricity flowing in wires, producing the telegraph and telephone. Then it was discovered that radio waves could be produced that traveled through space at the speed of light. By the use of this discovery, means were devised to make radio waves carry messages to any point on the surface of the earth in a fraction of a second. The result was radio and television. In this chapter you will study some of the ways man uses electricity to provide rapid, dependable wire and wireless communication.

PROBLEM 1. How is wire communication carried on?

DIRECT COMMUNICATION

Telegraph. The telegraph was one of the first practical devices used for long-distance communication by wire. The first telegraph instruments were invented by Samuel F. B. Morse, an American inventor, in 1837. The telegraph consists of a key, a sounder, and a battery. The sounder has two coils of small copper wire wound around a soft-iron core. A metal bar is held a short distance above the coils by a spring. As electricity passes through the wire in the coils, they become magnets and immediately pull the bar downward with a distinct click. When the electricity stops flowing through the coils, the spring pulls the bar away from the coils, and another click is produced as the bar strikes its upper support. The key is just a switch which opens and closes the electrical circuit. The sounder, the key, and the battery are wired together so that the key can be used to control the flow of electricity from the battery through the sounder. Such a simple telegraph system for sending and receiving messages is shown on page 558.

The earliest messages and many today are sent by a code made up of dots and dashes. If the key is closed briefly, the sounder produces two clicks close together. These two clicks indicate a dot. If the key is closed for a longer time, the two clicks do not occur so close together. This indicates a dash. The American Morse Code is used on land telegraph lines in the United States and Canada. The International Morse Code, which is also used in sending code messages by radio (see page 168), is used in most of the other countries of the world.

Automatic telegraph. In an automatic telegraph machine, the message is typed on a telegram blank and placed in a drum in the machine. This signals the operator at the telegraph office, and the drum on which the message was placed begins to rotate. As it rotates, the message is sent through wires to the telegraph office from which it is sent to its destination. When the telegraph operator has a message for the person with the automatic machine, he sounds a signal on the machine. Upon hearing the signal, someone in the office puts a sheet of blank paper on the drum. The operator then transmits the message from the central office to the machine, where it is printed on the blank telegram.

Teletype. A great many newspapers and radio stations receive their news over *teletype* machines. A teletype sending machine has a keyboard like that on a typewriter. The operator sending the message types it as he would on a typewriter. As the message is typed, electric impulses are sent over a wire to the receiving machine. These impulses cause the receiving machine automatically to type out the message as it is being typed by the sender. Teletype machines make it unnecessary to use any kind of code, and thus it is possible for anyone to read the message.

Telephotography. Perhaps you have wondered how pictures of events that occur in almost any part of the world can be printed in your newspaper a few hours after they take place. The pictures are sent either by wire or radio.

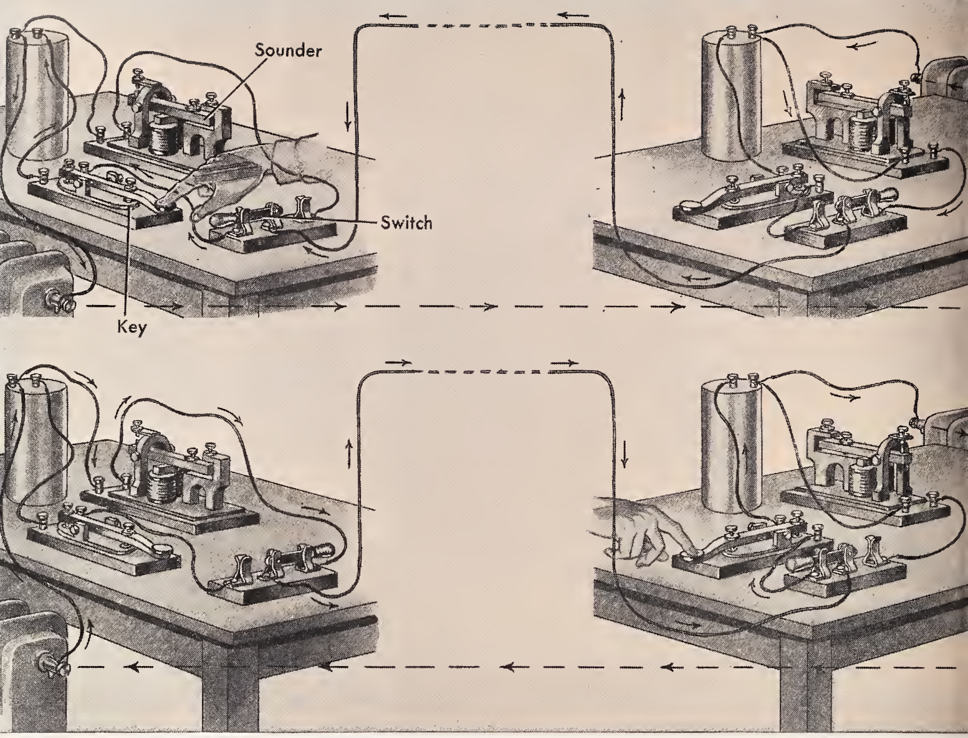


Diagram of a simple system for sending and receiving telegraph messages. In the top view, messages are being sent from the left-hand station to that on the right. Note the position of the switches at both stations. By reversing the switches, the right-hand station sends while the other receives as shown at bottom.

The picture to be sent is placed on a drum that can be made to rotate. As it turns, a small beam of light moves slowly from the top to the bottom of the rotating picture. The light reflected from the picture is focused on an electron tube which changes it into electric impulses. The impulses are transmitted by wire or radio waves to the receiving station. There the electric impulses control the amount of light used to expose a photographic film. When developed, the film shows a copy of the photograph that was transmitted.

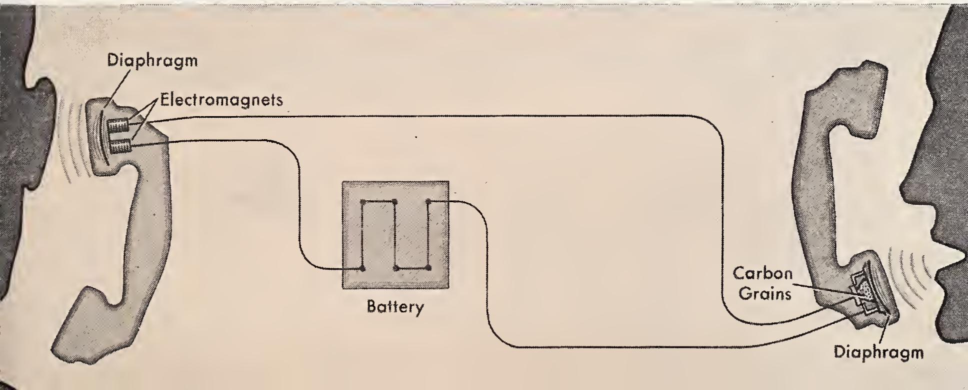
Telephone. On March 10, 1876, the first complete sentence was sent over a telephone invented by Alexander Graham Bell, an American inventor. The heart of the telephone transmitter is a small box of carbon grains through which direct-current electricity flows when the telephone is in operation. One side of the box is a thin, flexible diaphragm. The air vibrations from a sound source entering the mouthpiece strike the diaphragm and cause it to vibrate. As the diaphragm vibrates, it produces a varying pressure on the carbon grains. Large vibrations produce more pressure than small ones. When the grains are pushed closer together, their electrical resistance decreases and more electricity will flow in the circuit. As the pressure is decreased, the resistance increases and less electricity will flow. Thus the air vibrations striking the diaphragm cause the amount of electricity flowing through the carbon grains to vary in step with them.

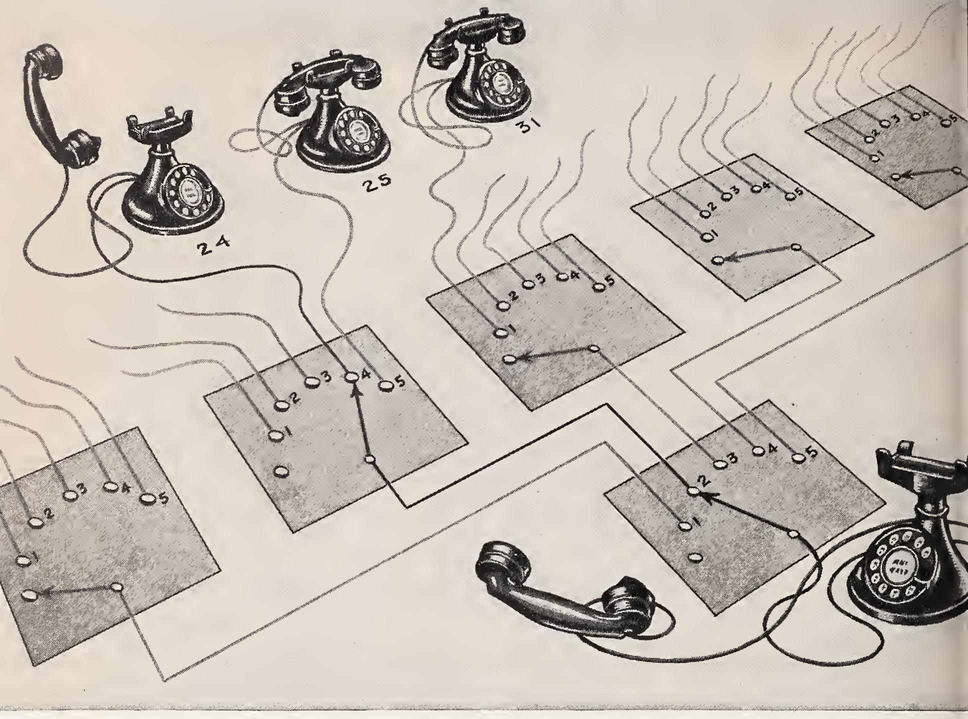
The telephone receiver contains a magnet upon which are wound some coils of small wire. A small iron disk is supported near, but not touching, the ends of the magnet. The varying electric current from the transmitter causes a similar varying current to flow through the coils in the receiver. This current causes the magnetic pull on the disk to vary so that it vibrates in step with the vibrations entering the transmitter. Vibrations from the disk enter the ear and reproduce the original sound.

When the electric current from a telephone transmitter is sent over long distances, it may become so weak that it will not produce a strong enough vibration in the receiver to enable anyone to hear the conversation. For long-distance transmission these currents are amplified by vacuum tubes similar to those used in a radio. The use of such amplifiers makes it possible for long-distance telephone calls to be heard as easily as local ones.

Dial telephones. In dial telephones a movable dial with ten positions is located at the base of the instrument. To call a telephone number, you place your finger in the opening in the dial which corresponds to the first letter or digit of the number, and then pull the dial around to the stop and release it. A spring returns the dial to the starting position. This process is repeated for each letter or digit in the telephone number being called. As the dial is returning to its starting position, it opens and closes an electric circuit a certain number of times, depending upon how far it was pulled from the starting position. Thus if 2 is dialed, the circuit may be opened and closed twice, for 5, five times, and so on. These circuit interruptions operate a mechanism at the central office which selects the proper telephone, and connects it with the telephone from which the call is being made. A simplified diagram showing the operation of one kind of dial telephone is shown in the illustration on page 560.

A simplified diagram of a telephone showing how electricity flows through the carbon grains and the electromagnets. Air waves vibrate the transmitter diaphragm, thus changing the pressure on the carbon grains. The changing pressure causes the carbon grains to change the amount of electricity flowing, which in turn causes the receiver diaphragm to vibrate so that one hears a sound like the original.





This simplified diagram shows the action of a two-number dial telephone system. When 2 is dialed on the phone in the lower right, the pointer moves to the number two position. When 4 is dialed, the pointer connected with number 2 moves to the 4 position, and telephone number 24 rings. In a similar manner any one of 25 telephones could be rung from the same telephone.

RECORDED COMMUNICATION

Speech and music. Phonograph recordings, wire or tape recordings, and sound motion pictures are examples of three common methods of recording and reproducing speech and music.

In all methods the vibrations are first used to produce electric voltages that vary in step with them. This is accomplished by a microphone like that used in radio broadcasting (see page 162). Second, the voltages from the microphone are amplified with electron tubes. In reproducing the sound, an electric voltage must be developed from a permanent record. This step is slightly different in each method, depending on the kind of material used for the permanent record. After the voltage is developed from the permanent record, it is then amplified with electron tubes and made to operate a loud speaker.

Phonograph recordings. The grooves of a phonograph record are waves varying both in length and height (see page 561). These wavy grooves are the permanent record of the vibrations from the original sound source.

To reproduce a program from a

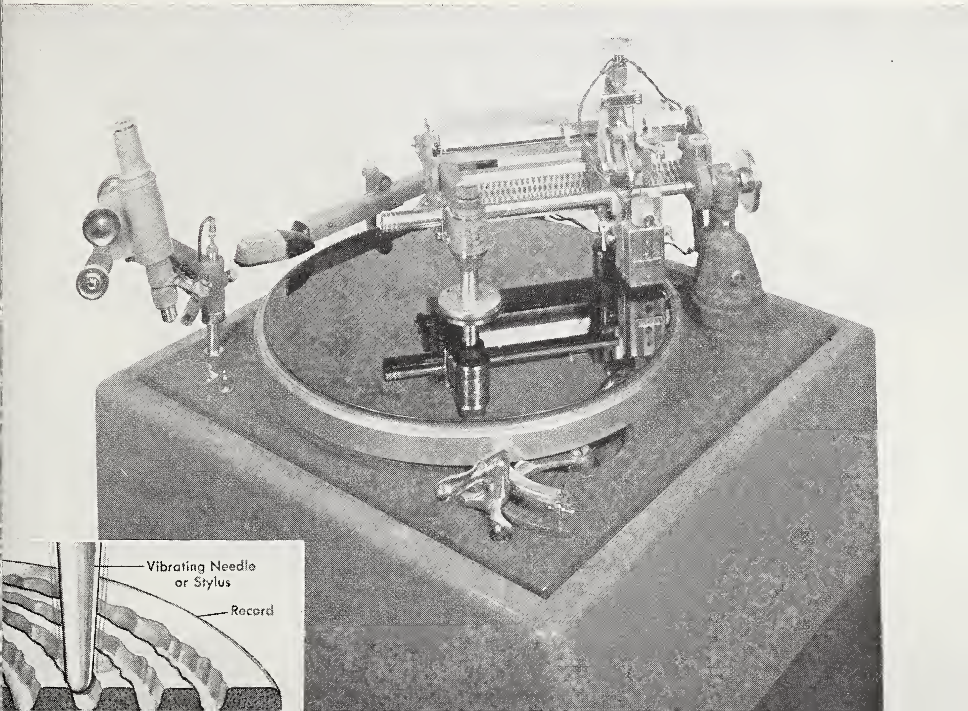
record, a needle, often called a *stylus,* is allowed to rest in the groove and an electric motor turns the record at the same speed at which it was recorded. As the record turns, the waves in the groove cause the stylus to vibrate back and forth, as shown below. The stylus is part of the *pickup* which changes the vibrations to electrical voltages. The small voltages developed by the pickup are amplified by electron tubes and operate a loud speaker.

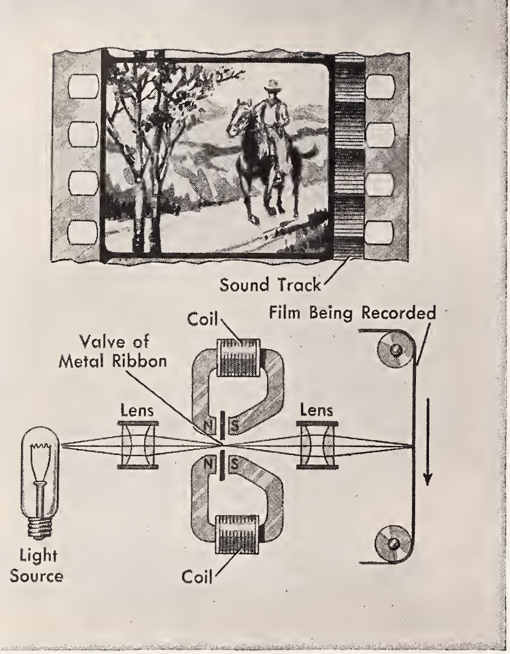
Wire and tape recorders. Wire and tape recorders depend upon magnetism for making the vibrations from a sound source permanent. A steel wire or a tape covered with microscopic particles of magnetic material, is pulled past the recording head at a constant rate of speed. The steel wire or the particles on the tape are magnetized as they pass the recording head. The amount of magnetism induced in the wire or tape depends upon the varying magnetic field of the coil in the recording head, which in turn is determined by the nature of the vibrations picked up by the microphone. Thus the original vibrations are responsible for a varying pattern of magnetism in the wire or tape.

In order to reproduce the recorded program, the wire or tape is pulled past

A disc recorder for making phonograph records. To make a record the air vibrations from a sound source are changed to electrical voltages by a microphone. The voltages are amplified and made to operate the cutting needle which moves back and forth sidewise to cut the wavy grooves in the record. This record is used to make a die with which durable records are stamped for commercial use.

Presto Recording Company





The sound track as made by one kind of recording. Sounds control electricity in the coils, causing the valve to open and close, thus varying the amount of light on the film.

some coils in the reproducer at the same speed at which it went through the recorder. In some small machines, the same head is used for recording and reproducing. The magnetism on the wire or tape produces a varying voltage in the coils, which is amplified and made to operate the loud speaker. Provision is also made in magnetic recording to erase the magnetism previously placed on the wire or tape so that it can be used again.

Motion pictures. In this system of recording, the amplified voltages from the microphone are made to control the amount of light that falls on the recording film. How this is accomplished in one method of film recording is shown above. To reproduce the program recorded on the film, a tiny beam of light is sent through the sound track and falls on a photoelectric cell, shown on page 563. This is one of the ways sound is recorded and reproduced for motion pictures.

Limitation of communication by wire. The development of wire communication helped solve the problem of speed in sending messages. They could be flashed from point to point in a nation or to all parts of the world in a short time. People could also talk with each other over long distances. However, neither the telegraph nor the telephone made it possible to communicate with large numbers of people directly. Furthermore, only those points that had wire facilities could be reached. What was needed was some method by which rapid communication could be made direct to a large number of people. Radio waves seemed to be the ideal medium for such communication. They were fast, were not limited to wires, could be made to travel over long distances, and could be received by the individual person in his home with a small amount of equipment. Thus wireless communication was developed, not to take the place of wire communication, but to supplement it.

SUMMARY

The development of the telegraph made possible long-distance rapid communication over wires. The magnetic effect of coils of wire carrying electricity is used to operate the telegraph. Automatic telegraph devices have made it possible to transmit almost a million messages daily in the United States. With the development of telephotography, it became possible to transmit pictures to many places in the world within a few hours. Speech and music can also be recorded or reproduced on special machines. The telephone modifies electricity with sound waves so that the sound can be reproduced almost instantly at great distances from its origin.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Electricity operates a telegraph sounder because of its (a) magnetic effect; (b) heating effect; (c) chemical effect; (d) sound effect.
2. Sending a picture over wires is known as (a) telegraphy; (b) teletyping; (c) telephotography; (d) telephony.
3. Many newspapers and radio broadcasting stations receive their news by (a) mail; (b) teletype; (c) television; (d) Morse code.
4. In a telephone, electric currents vary as the voice of the speaker varies because (a) you can speak over a telephone; (b) of the changing resistance of carbon grains; (c) electricity produces a magnetic field as it flows through a conductor; (d) electrons are changed into electricity by sound waves.
5. The effectiveness of communication by wire is limited primarily by (a) the speed at which messages can be sent; (b) the quality of sound reproduction; (c) the number of people who can be reached directly; (d) the kind of messages that can be sent.

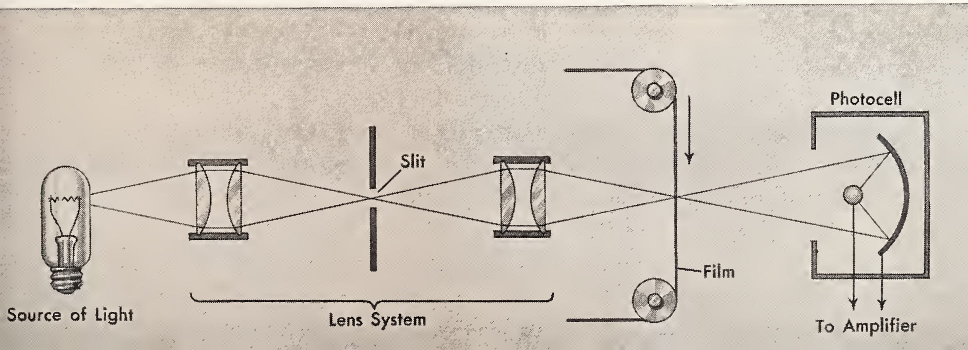
PROBLEM 2. How is wireless communication carried on?

RADIO WAVES

Wireless communication depends upon the use of radio waves. In Unit 4 we studied the nature of radio waves and how they are produced and used. Let us review these important ideas so that we will have them clearly in mind as we study the various ways of carrying on wireless communication.

The production and use of radio waves for communication. Radio waves are rapidly changing magnetic and electric fields traveling through space. They are ideal for rapid communication. They travel fast, about seven times

The method used in reproducing sound from motion-picture film. Light is sent through the sound track of the film (see page 562) and falls upon a photoelectric cell. Voltages in the photoelectric cell vary with the amount of light striking it. These voltages are amplified and operate a loud speaker.



around the earth in one second. They exhibit the wave characteristics of frequency, wave length, and amplitude. The radio-wave spectrum is made up of a great many individual waves, each with a definite frequency. Thus a wave of a particular frequency can be produced and controlled for the purpose of communication.

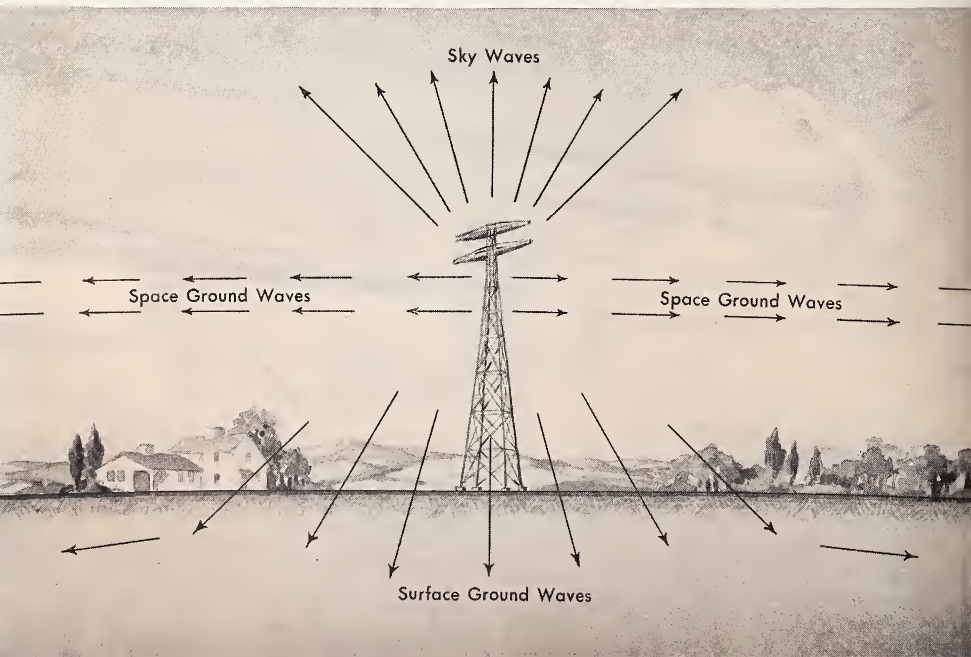
Vibrations from a sound source can be used to modulate radio waves so that they serve as carriers of speech and music. Radio waves are either amplitude or frequency modulated, depending upon whether the amplitude or frequency of the wave was modified by the sound. The equipment used to produce, modulate, and send out radio waves is called a *transmitter.*

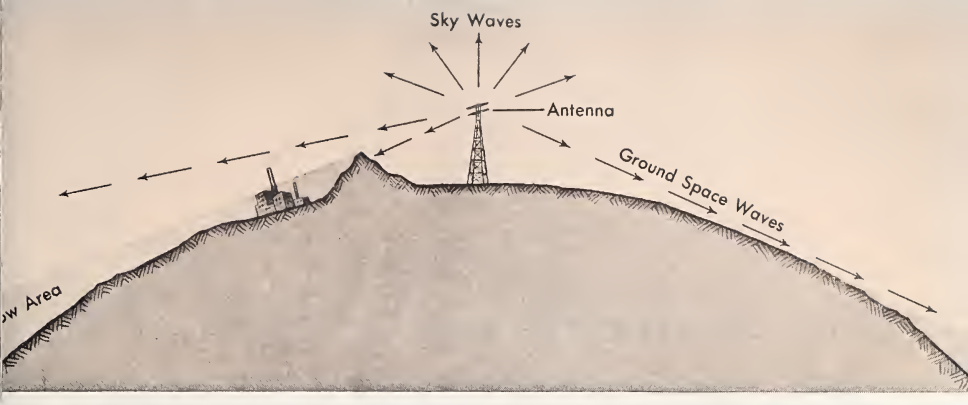
A modulated radio wave traveling through space will produce an electric voltage in any conductor it strikes. The voltage produced by the wave can be amplified with electronic tubes and made to reproduce the speech or music used to modulate the wave in the beginning. The equipment used in reproducing the speech or music from a modulated radio wave is called a *receiver.*

The success of wireless communication depends upon the radio wave's traveling from the transmitter to the receiver. A study of the behavior of radio waves as they travel will help you understand why different methods of radio communication are used.

Ground and sky waves. The radio waves leaving the antenna of a transmitter travel as *surface ground waves, space ground waves,* and *sky waves.* The radio waves sent by any transmitter normally travel in all three ways,

The paths of the three types of radio waves are indicated below. The behavior of each of these waves as it travels outward from the antenna depends upon the frequency of the wave and the nature of the materials through which it must travel. Successful wireless communication depends on effective use of each type wave.





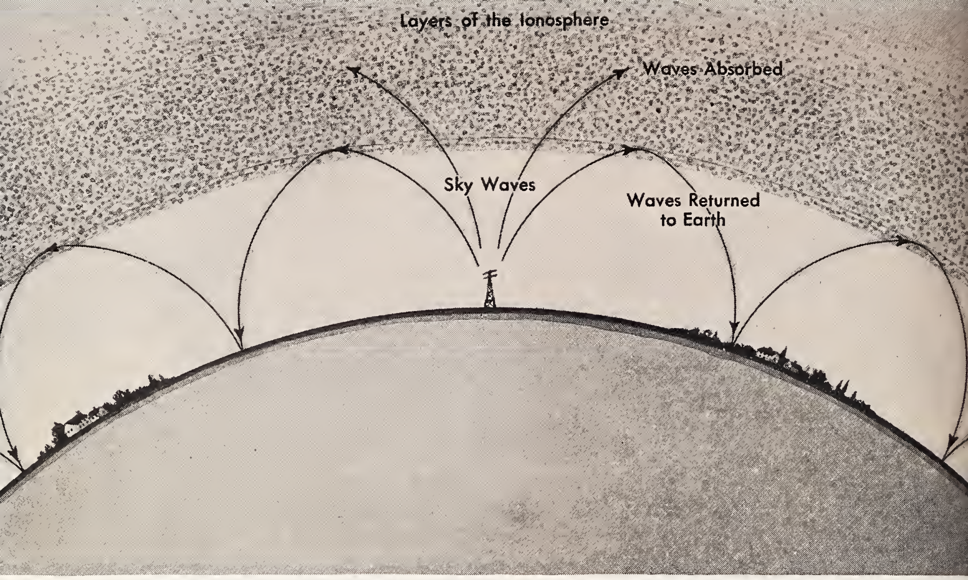
Radio waves used in broadcasting television travel in straight lines. The sky waves are not reflected back to the earth. Only those television receivers located between the antenna and the shadow areas can pick up signals directly from the antenna.

shown on page 564. Home radio receivers ordinarily depend upon the space and surface ground waves for reception from nearby broadcasting stations. Reception from distant stations is obtained only from sky waves.

Ground waves. Surface ground waves lose their energy rapidly as they travel through the surface of the earth. They become weaker and weaker, until finally they can no longer be received by home radios. The surface ground waves lose their energy less rapidly when they travel through water than through land. The land surface also varies in its ability to conduct these waves. Thus the nature of the surface of the earth surrounding a transmitter determines the distance at which its surface ground wave can be received.

The frequency of the radio waves sent out by any transmitter also affects the distance at which it can be received as a surface ground wave. The lower-frequency waves lose their energy less rapidly and can sometimes be received over distances as great as 1,000 miles. Higher-frequency waves, such as are used in FM and television, lose their energy so rapidly when they travel as surface ground waves that they are of no value for communication. FM and television receivers, therefore, must depend entirely upon space ground waves for reception.

Radio waves which travel as space ground waves are often affected by obstructions, such as mountains, hills, or tall buildings, between the transmitter and the receiver, as shown above. It is somewhat as though a large light were placed on top of the transmitting antenna. Any area that would be directly illuminated by the light would also be "illuminated" by the high-frequency space ground waves from the antenna. In such illuminated areas, reception from space waves will be good. Reception in any area shadowed by obstructions may be poor. Reception in such a location is known as *fringe area* reception. The curvature of the earth also affects high-frequency space ground waves much as an obstruction like a mountain does. For these reasons FM and television programs are best when the receiving antenna is "illuminated" by the transmitted signal, although some fringe area reception is satisfactory.



Some sky waves are absorbed and others returned to the earth by the ionosphere, depending upon the frequency of the wave and the condition of the ionosphere. Return of sky waves accounts for long-distance reception at night as well as for transoceanic reception of short-wave radio.

Sky waves. Sky waves are affected by a layer of the earth's atmosphere called the *ionosphere*. Beginning at about 60 miles above the earth, the ionosphere extends outward to about 200 miles. It consists of electrically-charged gas particles (*ions*). The charge on the gas particles is produced by the ultraviolet rays from the sun. Both the height and composition of the ionosphere change from daylight to darkness, with the seasons, and with a change in the amount of sunspot activity.

The effect of the ionosphere on sky waves of regular AM radio stations is shown above. During the day, the reception of stations is limited to ground waves which cover a distance of from 50 to 200 miles, depending on the nature of the earth's crust between the transmitter and receiver. As the sun goes down, the character of the ionosphere changes, and the sky waves may return to the earth from the ionosphere, increasing the range. For this reason, long-distance reception is possible with a standard radio at night but impossible during the daytime. The sky waves of short-wave radio stations are often returned to the earth from the ionosphere as shown above. In fact, they may go back and forth between the ionosphere and the earth several times before they become too weak to be received. For this reason, the sky waves from short-wave transmitters provide the most satisfactory wireless communication for distances greater than 1,000 miles. Transoceanic radio broadcasts and telephone service are largely carried on with the sky waves from short-wave transmitters. The sky waves of FM and television transmitters are usually absorbed by the ionosphere, and they are not useful for long-distance reception.

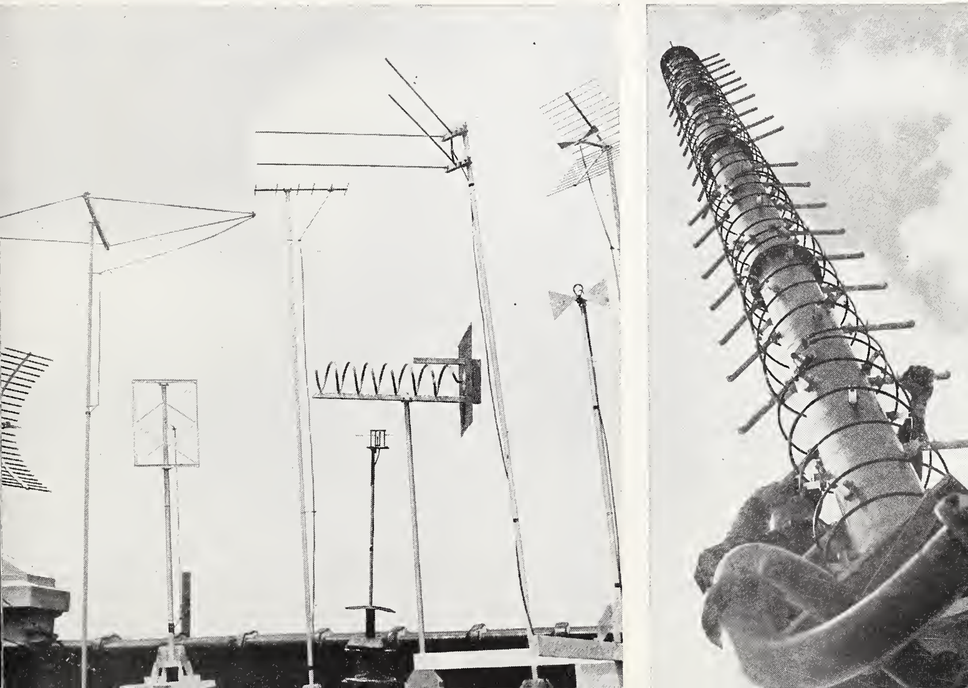
Fading. Radio reception which depends upon sky waves sometimes changes strength so rapidly that speech is difficult if not impossible to understand. This is known as *fading*. Fading may occur when two or more sky waves follow different paths from the transmitter to the receiver. When all sky waves arrive at the receiver so that their electric and magnetic fields reach a maximum value at the same instant, reception is strong and clear. If for some reason one sky wave reaches the receiver so that its fields are out of step with those of the other sky waves, the program fades away.

Sky waves are seriously affected by any great disturbance of the earth's magnetic field. Such disturbances are called *magnetic storms*. A magnetic storm may last several days during which time long-distance communication is difficult or, if the storm is severe, impossible. Sudden disturbances on the sun also may cause a complete fade-out of sky waves, making communication by means of them impossible.

Antennae. Several types of antennae (plural of *antenna*) have been developed for wireless communication in order to send and receive radio waves of different frequencies as efficiently as

The large antenna (at right) is one type designed for u.h.f. (ultra-high frequency) television broadcasting. Television stations using channels 14 to 83 which cover the frequencies from 470 to 890 mc. (megacycles) are known as u.h.f. stations. The small antennae are types especially designed for receiving u.h.f. stations. They bear such colorful names as "yagi," "double vee," and "bow tie."

Radio Corporation of America *General Electric*



possible (see page 567). Sometimes it is desirable to focus the radio waves in only one direction. With such an antenna, the waves can be focused, or *beamed,* toward the point with which communication is desired. The antenna directs the waves in a beam similar to the beam of light produced by a spotlight. Beaming radio waves helps insure maximum distance and dependability of two-way wireless communication.

The effectiveness of antennae for receiving radio waves depends upon their design and the manner in which they are installed. For example, the antennae used on television receivers are designed to provide the best possible reception on several channels. Best results are usually obtained in fringe areas when the antenna is as high as possible and pointed toward the station being received. Often a small motor is installed on the antenna mast so that the antenna can be rotated for best results from each station being received.

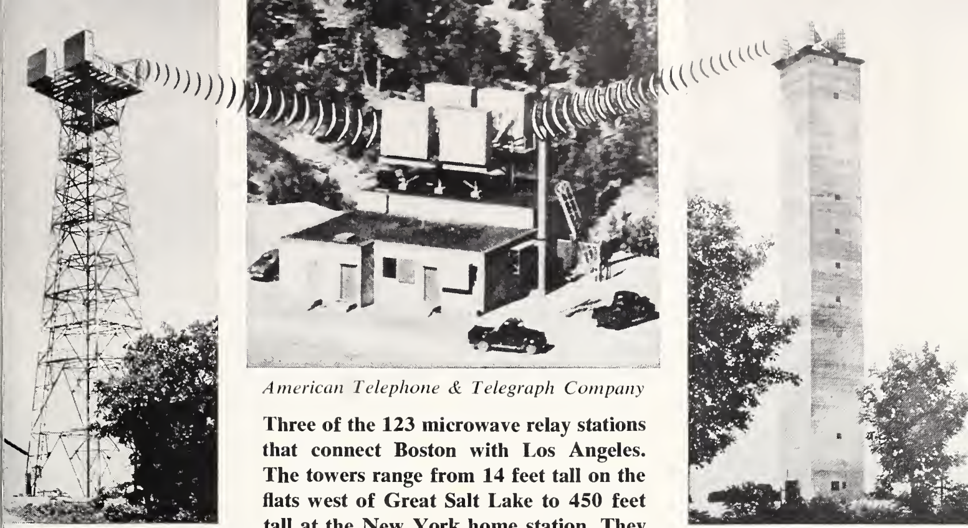
TWO-WAY WIRELESS SYSTEMS

When wireless communication can be carried on between two locations, the systems used are called *two-way systems.* Four main types of two-way wireless communication are used: (1) *guided-carrier,* (2) *medium-frequency,* (3) *very high-frequency,* and (4) *microwave.*

Guided-carrier systems. Railroads and electric power companies often use guided-carrier communication systems. In such a system, radio transmitters and receivers are used, but the waves carrying the signal are conducted by the power line, the railroad track, or the telephone and telegraph wires along the track. Although such a system is not strictly a wireless system, it is classed as a wireless system because the radio waves are guided over conductors that were not constructed for that purpose.

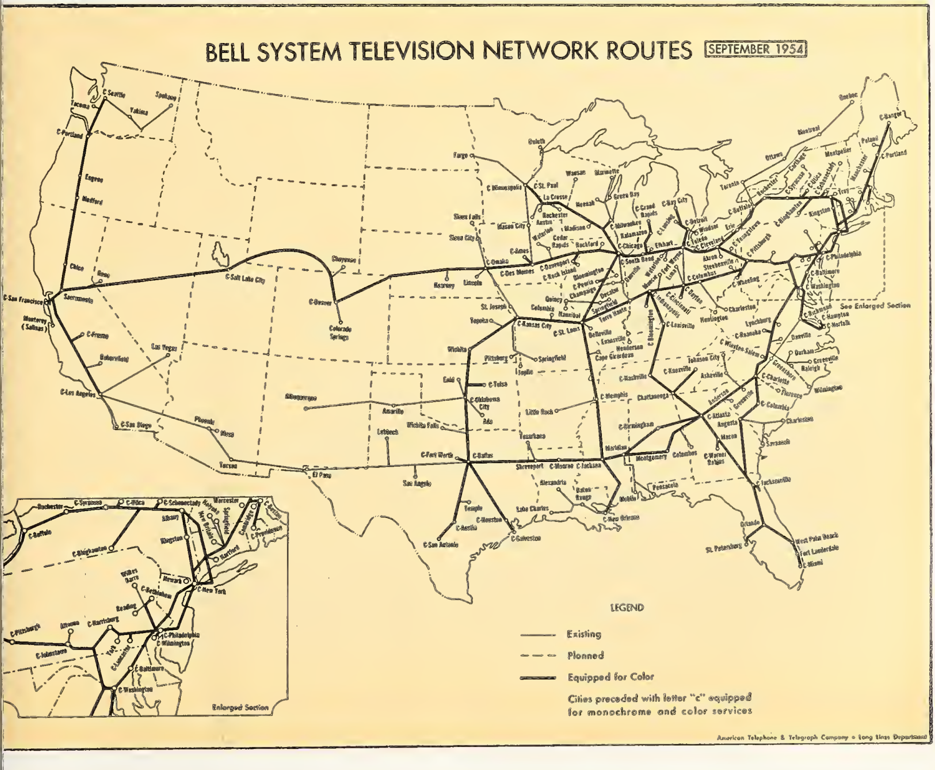
Medium-frequency systems. Medium-frequency two-way systems usually operate at frequencies somewhere between 2,000 to 4,000 kilocycles. They consist of an AM or FM transmitter, a receiver, and a suitable antenna located at each of the two places between which communication is being carried on. Both ground waves and sky waves are used. The ground waves provide consistent communication up to distances of 50 miles during the daytime. At night the sky wave makes communication possible anywhere from 300 to 800 miles, depending upon the frequency, season of the year, and locations of the transmitter and receiver. Medium-frequency systems are used by some railroads, by aircraft, and for maritime communication both at sea and on rivers, harbors, and the Great Lakes. These systems are also very useful in the event of disasters such as hurricanes which disrupt the regular-line communication facilities.

Very high-frequency systems. Very high-frequency systems differ from medium-frequency systems primarily in the frequencies of radio waves used. They operate on frequencies ranging from 30 to 162 megacycles per second. Because of the high frequencies used, communication is largely dependent upon the ground waves. Therefore the distance of communication ranges from 25 to 75 miles, depending upon the location of the stations, the nature of the earth's surface over which the signal must travel, and the exact frequency being used. These systems are used for



American Telephone & Telegraph Company

Three of the 123 microwave relay stations that connect Boston with Los Angeles. The towers range from 14 feet tall on the flats west of Great Salt Lake to 450 feet tall at the New York home station. They use all frequencies from 3,700 to 4,200 mc. and can handle east-west and west-east television signals as well as thousands of telephone conversations simultaneously. Each station receives signals from the one preceding it, amplifies and changes them if necessary and sends them on to the next station. Additional relay stations make it possible to send network television programs to any or all of the cities shown below.



short-distance communication by fire departments, police departments, the Forest Service, and railroads.

Microwave systems. Microwave systems cannot be used for communication at as great a distance as the other two-way systems described. Their range is limited because they operate at extremely high frequencies of from 300 to 5,000 or more megacycles per second. At such high frequencies only the space wave can be used effectively for communication. As you remember, when space waves are used, reception is poor or impossible below the horizon of the transmitter. However, microwaves can be beamed toward the receiver, reception does not vary at any time, and there is practically no static. Furthermore, it is possible to have a number of microwave systems operating throughout the country without interfering with each other, since the range of each transmitter is so limited.

For police and fire departments. Two-way wireless communication is extremely helpful to law-enforcement agencies. A single transmitter operating on medium or very high frequencies keeps police headquarters in touch with all patrol cars and with some officers on foot using small transmitters and receivers that weigh only about five pounds. With such a communication system, it is possible for the police to do their work a great deal more effectively.

Two-way wireless systems have made it possible for firemen to engage in such activities as fire-prevention work, inspections for violations of fire laws and removal of fire hazards, and still be readily available for fighting fires. If there is a fire, firemen who are away from the station can be called over their radios and given the location of the fire. In many instances they will arrive at the fire before the fire trucks do. At the scene of the fire, two-way communication is of great value in directing the efforts of the firemen. As you will recall, two-way wireless communication is also helpful in preventing and fighting forest fires.

In motor transportation. Bus companies have found that two-way communication enables them to carry on their business much more efficiently. When a bus failure occurs, the driver can immediately communicate with the nearest bus garage and thus get help in the shortest possible time. In case a passenger becomes ill, the driver can quickly summon what aid may be needed. Bus schedules are more easily maintained because drivers can be informed of weather and road conditions as well as stops to be made for picking up passengers.

Operators of truck lines find that two-way communication systems are extremely valuable. Drivers can keep the dispatching office informed of their location at all times, and can call for help if they need it. The dispatcher can change the route of the truck when necessary. Taxicab companies also have improved their service by installing two-way wireless systems by which cab drivers on the streets can be reached quickly and sent to pick up a nearby passenger.

In aviation. Two-way wireless systems are an extremely important aid to safe flying. They have proved so successful that many airports will not allow a plane to land unless it is equipped with radio so that the pilot can be given landing instructions. Radio also makes it possible for the pilot to

Stewart Warner Corp.

A personal two-way radio receiver with two of its possible uses shown. The inset at left is a close-up of the portable phone and antenna.

keep in touch with the airport at all times during a flight. The pilot can receive and give weather information, obtain permission and instructions to land at or depart from an airfield, make arrangements for any unusual needs of passengers before landing, and dispel anxiety when his plane is overdue. Aircraft radio systems must be light in weight and sturdily constructed, and be able to cover the distance necessary to maintain communication during the flight.

Mobile telephones. Telephone calls can be taken or placed from telephone-equipped cars, trucks, buses, or trains. If a businessman at his desk wants to call someone traveling in a telephone-equipped car, he either dials or asks for the vehicle operator and gives the number assigned to the car. The operator sends out a signal of the proper frequency from a radio transmitter which causes the telephone in the automobile to ring. The driver picks up the dashboard telephone and carries on the conversation.

Citizens' radio-communication service. The Federal Communications Commission has set aside a band of microwaves, to be used by persons who want their own wireless-communication system. This service has been named "Citizens' radio-communication service" by the FCC. Two-way radios for use in this band are small, light in weight, and can be used for communication over several miles under good conditions. Personal two-way radios may be useful to doctors in keeping in touch with their offices when on calls, to farmers working in fields some distance from the house, and on large construction projects where it may be necessary for the foreman to keep in touch with groups working in different places.

SUMMARY

Wireless communication depends upon radio waves traveling from the transmitter to the receiver with sufficient strength to enable the receiver to operate satisfactorily. Radio waves travel as sky waves and ground waves, each having characteristics which make it suitable for some types of communication but undesirable for others. By utilizing the characteristics of sky and ground waves of different frequencies, it is possible to design two-way wireless-communication systems that are successful in meeting a variety of communication needs.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The frequency of a radio broadcasting station is determined by (a) the rate at which electrons move back and forth in a tuned circuit; (b) the electric power upon which the station operates; (c) the kind of microphones used in broadcasting; (d) the height of the transmitting antenna above the station.
2. Radio waves that travel through the atmosphere near the surface of the earth are called (a) sky waves; (b) space waves; (c) surface ground waves; (d) modulated waves.
3. FM and television sets require special antennae because they depend upon (a) modulated waves; (b) sky waves; (c) surface ground waves; (d) space waves.
4. Extremely long-distance radio communication is possible because (a) a special kind of modulation is used; (b) the ionosphere returns the sky waves to the earth; (c) the ionosphere absorbs the sky waves; (d) surface ground waves are used.
5. A two-way communication system using radio receivers and transmitters but sending the wave along conductors such as rails which were installed for other purposes is called a (a) microwave system; (b) very high-frequency system; (c) medium-frequency system; (d) guided-carrier system.

CHAPTER ACTIVITIES

SOLVE A PROBLEM

Suppose you were reading a newspaper account of an open-air concert which had just been held in your community. The newspaper story stated that the concert had been broadcast to people overseas. The author of the article said that because of the marvels of modern science, people in England actually heard the music over their radios before many of the people in attendance at the concert heard it. You became interested in how it was possible for people in England to hear a concert before those in attendance heard it, and decided you would try to find out if the writer's statement was true.

PART 1

Following are a number of problem statements. On your answer sheet, write the number of the best statement of your problem.

1. How is music broadcast by radio?
2. Why was the concert broadcast to people overseas?
3. How is it possible for music to reach people in England before it reached some people in the audience?

PART 2

Following is a list of activities which might help you solve the problem you selected above. On your answer sheet, write the numbers of those activities which you believe would help you most in solving the problem.

1. Interview the conductor of the orchestra which played the concert.
2. Read about sound and radio in your science book.
3. Build a small radio.
4. Interview a radio engineer.
5. Interview your neighbor who is a musician.
6. Observe a film dealing with the way musical instruments produce sound.
7. Interview your science teacher.

PART 3

Following is a list of the facts you might have gathered by performing the activities selected from Part 2. On your answer sheet, write the numbers of those facts which you need to solve your problem.

1. Radio waves travel about 186,000 miles per second.
2. Radio waves are modulated by the sounds being broadcast.
3. Radio is a modern, rapid means of communication.
4. Sound travels about one fifth of a mile per second.
5. A microphone is used in broadcasting.
6. Some radios require special antennae.

PART 4

On your answer sheet, write the number of the statement below which is the best conclusion to the problem based upon the statements selected from Part 3 above.

1. It is possible for people in England to receive radio broadcasts from the United States.
2. The statement in the newspaper is true because of the great difference in speed between sound and radio waves.
3. The statement in the newspaper is false because sound cannot travel such great distances.
4. The truth of the statement cannot be judged because it is impossible to find out where the people in England who listened to the program lived.

UNIT ACTIVITIES

APPLY YOUR KNOWLEDGE

Six generalizations discussed in this unit are listed below, followed by a list of a number of situations related to communication. Select the generalization illustrated by each situation, and write the number of that generalization in the proper place on your answer sheet.

GENERALIZATIONS

1. Although vibrations may occur over a wide range of frequencies, only those between about 20 and 20,000 vibrations per second produce sound.
2. The frequency of vibration determines the pitch of the sound.
3. A magnetic field surrounds a conductor in which there is a current of electricity.
4. The amplitude of vibration determines the volume of sound.
5. The number of overtones determines the quality of sound.
6. Pressure is transmitted throughout an enclosed fluid without loss.

SITUATIONS RELATED TO TRANSPORTATION AND COMMUNICATION

1. A dog can be trained to obey a "silent" whistle.
2. The sound of a trumpet can be easily distinguished from that of a violin even though they play the same tone.
3. Automobiles with hydraulic brakes have been developed for safer driving.
4. The safety of railroad transportation has been increased by use of devices for testing rails.
5. Tightening the string on a violin makes it produce a higher tone.
6. The sound in a boiler factory is almost deafening.
7. The harder you beat a drum the louder it sounds.

MAKE VISITS

1. A telephone exchange
2. A radio broadcasting station
3. An airport
4. A telegraph station
5. A railway station (the dispatcher)
6. A television broadcasting station

CONSTRUCT THINGS

1. A simple telegraph sounder and key
2. A diagram showing the operation of the electrical system of an automobile
3. A simple radio receiver
4. A string telephone
5. A chart showing the altitudes to which various aircraft have ascended
6. A cigar-box violin

MAKE REPORTS

1. Aids for hard of hearing
2. Jet-powered aircraft
3. Facsimile
4. Methods of testing automobile drivers
5. Semaphore signaling
6. Radio as a career
7. Submarines
8. Alexander Graham Bell
9. Transoceanic telephone cables
10. New types of transmissions on automobiles
11. Coaxial cables in communication
12. Electronics in communication

CONDUCT EXPERIMENTS, DEMONSTRATIONS, OR OBSERVATIONS

1. Using a stop watch and a starter's pistol, measure the speed of sound as it travels from end to end of a football field. Compare the measured value with the accepted value you have learned for the speed of sound.
2. Examine the transmitter and receiver of an old telephone instrument. Describe how each part observed performs its function.
3. Demonstrate by using fans, as shown on page 520, how the fluid drive operates.
4. Demonstrate how different musical instruments are tuned.

5. Visit a museum to observe exhibits on the history of communication.

READ ABOUT TRANSPORTATION AND COMMUNICATION

Ahnstrom, D. N. *The Complete Book of Helicopters*. Cleveland: The World Publishing Company, 1954.

The author explains how the "egg beater" or "whirlybird" species of flying machine evolved and describes the extraordinary range of its uses.

Baer, Marian E. *Sound; an Experiment Book*. New York: Holiday House, Inc., 1952.

Experiments dealing with properties of sound, vibration, frequency, reverberation, and resonance. For young scientists and young people interested in music.

Batchelor, Julia Forsyth. *Communication, from Cave Writings to Television*. New York: Harcourt, Brace and Company, 1954.

Simple and informal history of communication by eye, ear, and touch, from man's first writing to today's scientific achievements.

Beeler, N. F., and Branley, F. M. *Experiments with Airplane Instruments*. New York: Thomas Y. Crowell Company, 1953.

Simple experiments explaining basic principles and functions of the various airplane instruments.

Billings, Henry. *Superliner S.S. United States*. New York: The Viking Press, 1953.

Construction of this dual-purpose ship is described, with a brief review of the problems of shipping, and a look at the future of American passenger and merchant marine service.

Bunce, William. *Freight Train*. New York: G. P. Putnam's Sons, 1954.

This text explains the purpose of each car, what the mysterious markings on their sides mean, how coupling devices and other equipment work, how the railroad lines keep track of the travels of their trains.

Coombs, Charles. *Skyrocketing into the Unknown*. New York: William Morrow and Company, 1954.

Story of jet and rocket developments in the United States and their bearing on the possibility of space travel in our lifetime.

Crump, Irving. *Our Tanker Fleet*. New York: Dodd, Mead and Company, 1952.

Exciting story of the little known tanker service and the vital part it plays in the world's economy.

Floherty, J. J. *Men against Distance*. Philadelphia: J. P. Lippincott Company, 1954.

Discusses the telephone, telegraph, Atlantic cable, wireless, and radio, with biographical material about the inventors.

Gould, Jack. *All about Radio and Television*. New York: Random House, Inc., 1954.

Discussion of the operation of radio and television with simple instructions for building a radio.

Growden, Gordon A. *Freighters and Tankers of the U.S. Merchant Marine*. New York: G. P. Putnam's Sons, 1954.

This is an attractive album of merchant vessels. It has 26 full-color drawings with captions describing the principal cargo of each type of ship, its speed, hoisting machinery, propulsion engines and other features.

Hertz, Louis H. *Making Your Model Railroad*. New York: Thomas Y. Crowell Company, 1954.

Advice on building model railroads from the simplest to those with elaborate layouts, including scenery and other accessories.

Lewellen, John. *Birds and Planes: How They Fly*. New York: Thomas Y. Crowell Company, 1953.

Principles of flight explained in simple language with clear line drawings.

Lindbergh, Charles A. *Spirit of St. Louis.* New York: Charles Scribner's Sons, 1953.

Inside story of the 1927 trans-Atlantic flight.

Ross, Frank. *Flying Windmills.* New York: Lothrop, Lee and Shepard Company, Inc., 1953.

The story of the helicopter, stressing its growing importance.

Ross, Frank. *Young People's Book of Jet Propulsion.* New York: Lothrop, Lee and Shepard Company, 1954.

Principles of jet propulsion explained with brief descriptions of different types of jet and rocket powered aircraft. Well illustrated with excellent photographs.

Tunis, Edwin. *Oars, Sails and Steam.* New York: The World Publishing Company, 1952.

History of boats from the earliest days and the simple canoe to the present luxury liner told in brief text and line drawings.

American Forest Products Industries

By the use of science plywood is adapted to form beams for a dairy barn.

unit 13 MATERIALS OF CONSTRUCTION

MODERN living, which depends so much upon the things man has constructed, would be impossible without the use of vast amounts of materials found in and on the earth. Many materials are found in a usable form; it is necessary only to shape them as desired. Others must be treated so that desirable substances they contain can be extracted. Still others are used by man to make materials that have no counterpart in nature.

Man did not always possess the knowledge necessary to enable him to use the wide variety of materials he now uses. Different ages are sometimes identified by the particular material most widely used for constructing the things needed in that age. Thus there have been the Stone Age, the Bronze Age, and the Iron Age. By this classification, we are still living in the Iron Age. This means that although we use a great variety of materials, our use of iron in so many ways in such large amounts is an important characteristic of the age in which we live. As he searches for and uses materials for his needs, he increases both the variety of materials he uses and his own skill in using them.

In this unit you will learn what types of materials man must have to meet many of his needs, how he tests them to be sure they are satisfactory, and how he puts them to use. You will also learn how he produces some materials that do not occur naturally, and the ways in which these man-made materials better meet his needs than natural ones previously available to him.

New York Port Authority

Many different materials with a variety of properties were used in the construction of this bridge.

chapter 30 SELECTION OF MATERIALS

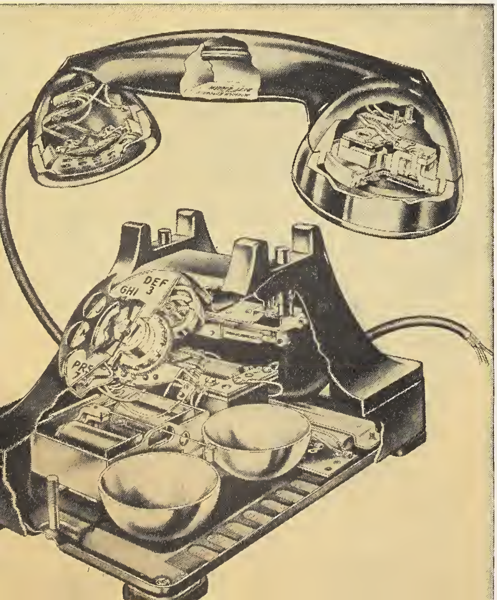
IF you just look around and begin naming the different kinds of materials used in making the many things you use every day, you may be amazed at their variety. A house, for example, may have a foundation built of concrete, stone, or cinder block; walls made from wood, concrete, stone, or brick; a roof covered with asbestos, wood, or slate shingles; plumbing and heating systems made from iron, brass, copper, and other metals; and it may be decorated with different kinds of paint of several colors. These materials have been collected from a variety of sources and brought together to make the house. Each material is selected and used in the house because it best fits the use to which it is being put. By using scientific methods, we have been able to test materials to discover which is best for each need and to develop new ones to meet changing needs.

PROBLEM 1. What kinds of materials do we need?

USES OF MATERIALS

Forty-six different materials are used in making a modern telephone instrument like that shown below. Although the telephone is only one of the many devices we construct for our use, it is a good example of the variety of different materials necessary to meet our needs in constructing things.

Strong materials. Strong materials are needed in the foundations of large buildings in order to support the load placed upon them. For example, the Empire State Building in New York City is 1,250 feet tall. It is made of limestone, concrete, and steel. Its foundation must support millions of pounds without being crushed, and must be built upon bedrock that will give it a firm base.



The 46 materials used in this instrument come from many parts of the world. They include gold, silver, leather, and unexpected substances such as ink, borax, and asphalt.

WE and Telephone Service

The roadways of some bridges, such as that shown on page 579, are supported by large cables suspended from towers. Both the towers and the cables must be constructed of materials that will support the tremendous loads upon them. The roadbeds of railways and highways must also be made of materials that will withstand the heavy loads carried over them at high speeds. Highways are damaged when the loads carried over them are heavier than they are built to support. For this reason, most states check the loading of trucks and keep overloaded trucks off the highways.

Modern airplanes would be impossible without strong, light materials. The use of light metal has also reduced the total weight of airplanes, trains, ships, and buses without any loss in strength.

You will recall that an airplane flying at supersonic speeds is heated to high temperatures by the friction of the air over the plane's surfaces. This creates a problem for the builders of such airplanes, because many of the materials ordinarily used become weak at high temperatures. Scientists are searching for materials which will stay strong at high temperatures to use in such airplanes.

Materials that are easily shaped. Materials must be formed into many different shapes to construct the things we need. They are sometimes formed in wires, rods, and bars of different sizes. Some wires are so small that they can scarcely be seen with the unaided eye, while rods or bars may be several inches thick. Wires are used for carrying electricity, binding packages, making cables, and building fences. Rods and bars are used for buildings and machinery.

For some uses we need sheets of materials. Some sheets may be thinner than those used to wrap candy bars; others, such as the armor plate on a battleship, are several inches thick. Sheets of material are pressed in various shapes to form such things as automobile bodies, cooking utensils, and cabinets.

Some of the objects we use are made from materials that can be easily molded into the desired shapes. For example, bricks, some dishes and parts for machinery, and the case for the telephone instrument are made in this manner.

Materials to control energy. As you will recall from Unit 5, materials which can be used as insulators or conductors are needed to control electricity. The conductor carries electricity, while the insulator keeps it from leaving the circuit provided by the conductor.

In Unit 6 you learned that materials vary in their ability to transfer heat. Cooking utensils must be made from those that transfer heat readily. On the other hand, the walls of homes are insulated with those that do not transfer heat. Many of the things we construct operate successfully because of the use of materials that control the transfer of heat in the desired manner.

Materials are sometimes used to control one or more types of radiant energy. For example, the materials used in windowpanes and lenses for optical instruments allow light to pass through in a manner that makes vision possible. As you will recall, ordinary window panes do not allow ultraviolet light to pass through them. If it is desirable to transmit ultraviolet light, other materials must be selected. We have also seen how infrared radiant energy can be controlled by selecting materials that will either reflect or absorb it.

Many electric devices depend upon materials that become magnetized when placed in a magnetic field. Among these are electric motors, generators, doorbells, telephones, and radios. On the other hand, in instruments such as watches, it is desirable to use materials that are not easily magnetized. For example, if the balance wheel of a watch should become magnetized, the watch would no longer be accurate.

Durable materials. A desirable characteristic of most of the things we make is that they should be durable, that is, last a long time. Chemical action, which causes some materials to rust or tarnish rapidly if exposed to the air, may affect both the durability and beauty of an object. Because friction wears away some materials, they cannot be used in tools made for grinding, cutting, and filing. Pavements, sidewalks, and floor surfaces that are subjected to heavy use should also be made from materials that will not readily wear away.

SUMMARY

We need a variety of materials for constructing the things we use. We need some materials that are strong, some that can be formed into various shapes, some that can be used in controlling energy, and some that will resist wear and chemical action. We also often need materials that combine all of these properties.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words which should be substituted for the italicized ones to make the statement true.

1. In order to satisfy all the requirements placed upon a telephone instrument described in this problem, *forty-six* different materials were used in its construction.
2. The foundation of a large building supports such a tremendous load that the materials used for the foundation must be *easily shaped*.
3. Modern airplanes would be impossible without strong, *light* materials for use in their construction.
4. The materials used in electric conductors and insulators are selected in terms of their ability to *produce* electricity.
5. The use of glass window panes to allow light to enter a room is an example of a material being used to control *heat*.

PROBLEM 2. What properties must materials have to meet our needs?

PROPERTIES AND THEIR USES

Each of the materials used in the telephone (page 580) was selected for the instrument because of certain properties it had. *Property* is a term used in describing the characteristics of a material, such as its hardness and its color.

Selection of materials. Before materials are selected for use in constructing things, their properties are carefully studied. Many industrial concerns maintain laboratories staffed by scientists who study the properties of materials. The National Bureau of Standards, supported by the federal government, also operates such laboratories, where scientists attempt to discover and produce materials with more desirable properties than those available.

Materials are often selected for construction by using the *if—then* method. The uses to be made of the material are first determined. The properties which such materials must have are then described. For example, suppose a designer is planning a piece of metal equipment to be used on an ocean-going ship. Among other things, the equipment needs to be made of a metal that will not be affected by salt water. The designer may consult the reports of scientists who have tested a number of metals for their resistance to corrosion by salt water. He may then select the one which has proved to be most resistant to corrosion. The process of selection might be summarized as follows:

if resistance to corrosion by salt water is desired;
if it is found that one of several metals tested in the laboratory resists corrosion best,
then the most resistant material would be the proper one to use for constructing the equipment.

It should be remembered, however, that very few materials are used under conditions such that only one property is considered important. A material is usually selected because it has several desirable properties.

Scientists have described a large number of properties which materials should possess in order to be used for different purposes. They have also devised ways of measuring the extent to which any material possesses a certain property. Although all the properties and measurements for them cannot be described in this book, some of the most important and widely used ones will be discussed so that you may see how scientists are helping man make better use of materials to meet his many needs.

Properties indicating strength. Several different kinds of strength are important, one of the most important being *elasticity*. Elasticity refers to the force needed to overcome the resistance a material offers to being stretched, compressed, or twisted out of shape before it is permanently deformed. A scientist would consider rubber, which we commonly think of as highly elastic, to be less elastic than many other materials because it can be easily stretched. Steel, on the other hand, is one of the most elastic materials known. This makes steel valuable for use in watch and automobile springs.

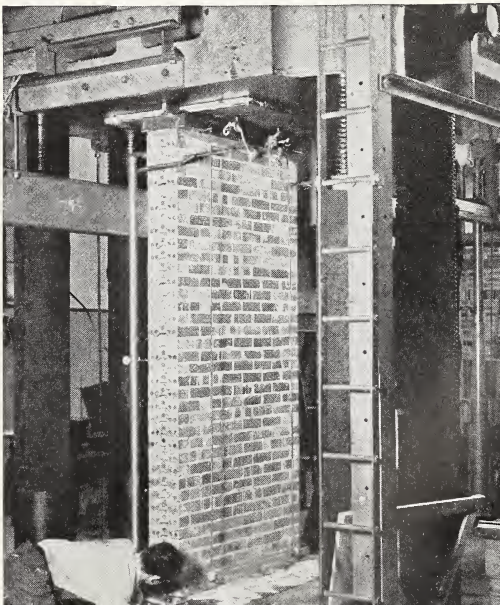
There is a point in stretching at which a material will not return to its original shape; it may even break if enough force is applied. This point is known as the *breaking point*. The breaking point of a wire or cable, also called its *tensile strength*, is measured by the number of pounds a square inch of material can support before it breaks.

Materials used in the foundations of buildings must support heavy loads without being crushed. The ultimate strength of such materials in resisting crushing loads is known as *compressive strength*. Sometimes both the strength and weight of a material are important considerations. In building airplanes, for example, the weight of a material is of first importance, since some of the strongest materials such as steel would be too heavy. Engineers judge the weight of materials by comparing their *density*, expressed in grams per cubic centimeter or pounds per cubic foot.

Properties allowing for easy shaping. In order to make some things, it is necessary to use materials which can be drawn into fine wires. The property making it possible to do this is called *ductility*. Platinum, which possesses

In a laboratory a 10-million-pound testing machine is used to determine the compressive strength of a brick wall, in connection with development of a new house design.

National Bureau of Standards



this property to a high degree, is used in telescopes in place of spider's thread formerly used. In electric light bulbs the filament is a coil of wire of tungsten, a highly ductile material.

It is sometimes necessary to shape materials into thin sheets by rolling, pressing, or hammering. The property making this possible is called *malleability*. Gold is so malleable that sheets thin enough to be stacked 280,000 in a one-inch-high pile can be made from it. Silver, copper, tin, platinum, lead, zinc, iron, and nickel are also malleable.

Most solid metals can be formed into various shapes if they are heated until they melt, and are then poured into molds of the desired shape to cool. To make use of this property, it is necessary to know the *melting point* of the material, that is, the temperature at which it melts.

Plastics, too, can be molded while they are soft into different shapes which they will hold when they harden.

For building, materials must be chosen that can be cut, scraped, or sawed into various shapes. Because wood possesses this property to a high degree, it has always been a widely used building material.

Properties useful in controlling energy. You will remember from your study of electricity that the *resistance* of a material to electric current must always be considered when selecting materials for use with electricity. A material which offers very little resistance may be used to conduct electric currents from one place to another. Materials with high resistance can be used as insulators to confine the electric currents to the paths provided by the conductors, and for heating elements of electrical appliances.

It is often important to consider the *magnetic* properties of a material. For example, soft iron will become strongly magnetized when placed in a magnetic field, but will lose its magnetism when the field is removed. This makes it good for use in electromagnets in doorbells, telephones, radios, and loading cranes for magnetic materials. Steel, on the other hand, retains its magnetism after the magnetic field is removed. For this reason, it is used in making permanent magnets like those in a compass needle.

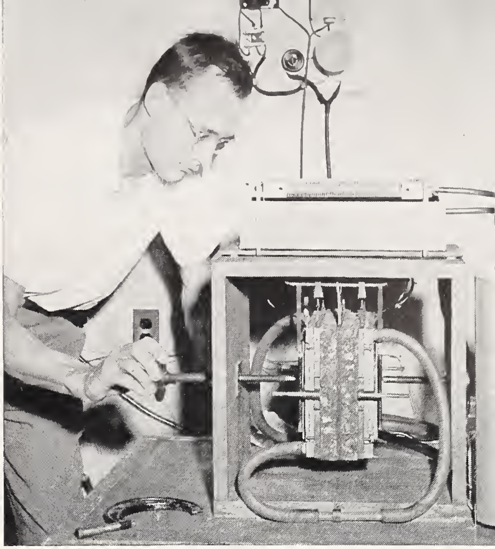
The property of a material to conduct heat, known as *thermal conductivity,* must often be considered. When it is necessary to conduct heat, metals like silver, copper, or aluminum are good; when heat insulators are required, spun glass, asbestos, and cork are selected.

Another consideration in the selection of materials is their *expansion* and *contraction* with changes of temperature. For example, a steel bridge 1,000 feet long will vary about half a foot in length between winter and summer temperatures (0° to 90° F); therefore, the bridge must be built so that this change in length will not damage the roadway. Materials which vary little in length with changes of temperature are useful for clock pendulums and delicate measuring instruments.

Radiant energy, as we have seen in Unit 4, is often controlled by the use of materials with certain properties. A *transparent* material allows radiant energy to pass through it with almost no effect. Glass and some plastics are transparent to light, and can be shaped into lenses with curved surfaces to be used for its control. A material through which radiant energy cannot pass is known as *opaque*. Materials vary in the degree to which they are opaque to radiant energy. Cloth, for example, is opaque to light but may be almost transparent to infrared rays. Window glass is transparent to light but opaque to ultraviolet rays. An understanding of the particular opaqueness of a material is often important in planning the use to which that material may be put.

Properties indicating durability. When a material must be selected for its durability, that is, its ability to last a long time, the properties of *hardness* and *resistance to chemical activity* are taken into account. As you know, some materials are harder than others. You can easily scratch a piece of wood with a nail, and a nail with some kinds of steel. Steel can be scratched by a diamond. Hardness refers to the ability of one material to make scratches on another, and scales of hardness have been devised to measure this property.

Durability for out-of-door use requires a high degree of resistance to combinations of moisture, oxygen, and other chemicals in the air. Gold is most durable in this respect, and for this reason, as well as for its beauty, it is often used in thin sheets on the domes of some buildings. Copper, lead, tin, zinc, and aluminum are also often used outside. Iron and steel, on the other hand, rust rapidly when exposed to the atmosphere, and when they are used outdoors they need a protective covering of paint. The ordinary tin can is really made from steel thinly coated with tin to make it resistant to chemicals contained in the contents of the can. Many parts of automobiles are made of steel covered with a layer of chromium to protect them from the weather as well as to add beauty.



National Bureau of Standards

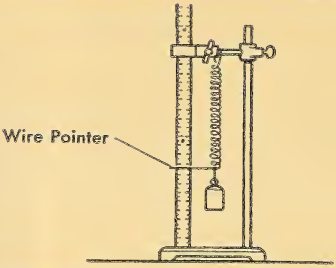
Apparatus developed at the National Bureau of Standards to measure the thermal conductivity of insulating materials. Such measurements make it possible to determine how well a certain material will insulate a home.

Materials which will come in direct contacts with chemicals, as is often the case in industry, must not react to the chemicals. Platinum, which resists the action of most chemicals, is often used in laboratory work. Glass and porcelain are also unaffected by many chemicals, although wax must be used for containers for hydrofluoric acid which will dissolve ordinary glass bottles.

SUMMARY

In selecting materials for their strength, it is important to consider the properties of elasticity, tensile and compressive strength, and density. The ease with which materials can be shaped into various forms is indicated by their ductility, malleability, melting point, and by whether or not they can be easily cut. The desirability of material for use in controlling energy is determined by the extent to which it permits the transfer of electricity, heat and radiant energy through it. Both the hardness of a material and its resistance to chemical activity are important properties in determining what its durability is.

OBSERVATION



What to observe. The elasticity of a spring.

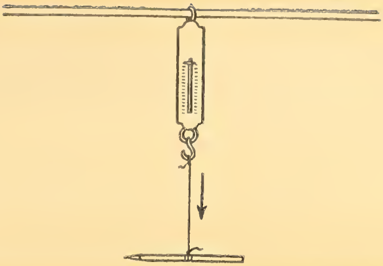
How to observe it. Suspend a coil spring from a support and attach a short piece of wire to the bottom of the spring to serve as a pointer. Stand a meter stick upright near the spring so that the pointer rests at some centimeter mark on the meter stick. Record the centimeter reading on the meter stick. Now attach a 50-gram weight to the spring, and read and record the new position of the pointer on the meter stick. In a similar manner, read and record the pointer position when 100 grams, 150 grams, 200 grams, and 250 grams are attached to the spring. You can record your readings in a table similar to the following:

ELASTICITY OF STEEL SPRING

LOAD	POINTER READING IN CENTIMETERS	STRETCHING OF SPRING IN CENTIMETERS FOR EACH ADDITIONAL 50 GRAMS	LOAD	POINTER READING IN CENTIMETERS	STRETCHING OF SPRING IN CENTIMETERS FOR EACH ADDITIONAL 50 GRAMS
0 grams		Starting point	150 grams		
50 grams			200 grams		
100 grams			250 grams		

Interpretation of your observation. Write one sentence describing the extent to which a spring stretches each time the load is increased by 50 grams.

DEMONSTRATION



Generalization to be demonstrated. Materials have different breaking points.

What you need. Spring scale capable of registering several pounds; several sewing threads the same size but made from different materials.

What to do. Fasten the spring scale to a strong support. Cut five 18-inch pieces of one kind of thread and tie a small loop in both ends of each piece of thread. Fasten one loop on the hook of the balance and insert a pencil in the loop on the other end. Pull slowly and steadily on the thread until it breaks, watching the scale reading as you pull. Record the scale reading at the breaking point. Repeat the above procedure with each of the other four pieces of the same thread. Determine the average value of the breaking point for the five pieces and use the average as the breaking point for the kind of thread being tested. Determine the breaking point for each of the other kinds of thread in the manner described above.

What to observe. What variation is there in the breaking point of the different kinds of thread?

What does it mean? 1. Does the evidence you obtained tend to prove or disprove the generalization at the beginning of the demonstration?

2. What assumptions would you have to make to use the evidence obtained in this demonstration as proof of the generalization being tested?

TEST YOURSELF

In the proper place on your answer sheet write the letter of the ending which best completes each statement.

1. The resistance of a material to being stretched, compressed, or twisted out of shape is known as (a) elasticity; (b) ultimate strength; (c) density; (d) hardness.
2. Of these materials, the one with the

greatest tensile strength is (a) lead; (b) copper; (c) steel; (d) aluminum.

3. The weight of a substance in pounds per cubic foot is known as its (a) tensile strength; (b) compressibility; (c) elasticity; (d) density.
4. The ability of a material to be drawn into a wire is known as (a) malleability; (b) ductility; (c) elasticity; (d) tensile strength.
5. A material which does not allow radiant energy to pass through it is called (a) transparent; (b) opaque; (c) elastic; (d) hard.

CHAPTER ACTIVITIES

SOLVE MATHEMATICAL PROBLEMS

1. If a steel cable 100 feet long stretches 0.27 inch when loaded with 50 pounds, how much would the wire stretch if loaded with 500 pounds? (Assume the breaking point is not exceeded when the 500-pound load is added.)

2. If 1,000 feet of the cable in problem 1 were loaded with 500 pounds, how much would it stretch?

3. If duralumin has a tensile strength of 60,000 pounds per square inch of material, what load could a wire having a cross section of half a square inch support?

4. Suppose a cube of metal was exactly 2 feet along each edge and weighed 1,352 pounds. What is the density in pounds per cubic foot of the metal?

5. If a steel bar 100 centimeters long expands 0.11 centimeter when its temperature is raised 100°C, how much will a steel bar 1,300 centimeters long expand when its temperature is raised 200°C?

REVIEW YOUR UNDERSTANDING

Four general classes of materials, in terms of their ability to satisfy man's needs, are listed below, followed by a list of twelve properties of materials. Beside the number of each property, write in the proper place on your answer sheet the number of the general class with which that property is most closely associated. **Do not write in your textbook.**

GENERAL CLASSES OF MATERIALS

1. Strong materials
2. Materials that are easily shaped
3. Materials to control energy
4. Durable materials

PROPERTIES OF MATERIALS

1. Malleability
2. Opaqueness
3. Compressive strength
4. Electrical resistance
5. Elasticity
6. Tensile strength
7. Ductility
8. Transparency
9. Thermal conductivity

Douglas Fir Plywood Association

The man at the machine clips a continuous sheet of veneer to desired sizes as it passes before him. Later the sheets are banded together into 3, 5, or 7-ply panels of plywood.

chapter 31 USE OF MATERIALS

THE hunt goes on ceaselessly for new materials that will meet our needs better than those we have used in the past. The earth, including the plants and animals that live upon it, is our only source for these materials. Therefore, almost every substance in the earth's crust, every plant, and every animal living on the earth have been studied to see how they can best be used. A substance, or a material from plants or animals, may be used in its natural form; it may be processed to give it properties it does not naturally possess; or it may be used as one of the ingredients from which new kinds of materials not found naturally on the earth are created. In these three ways the number and variety of materials available have been increased enormously by use of science.

PROBLEM 1. How do we use materials obtained from plants and animals?

We depend upon plants for many materials: lumber for buildings, fibers to make cloth; wood for some paper and rayon, and for rubber. Animals too furnish many of the materials man uses for constructing things. From them we get beautiful furs, silk and wool fibers for fine textiles, glue used in manufacturing, skins for leather. All these products must be treated in some way, however, before they are suitable for use in constructing things. In this problem you will learn some of the processes through which they must go.

PRODUCTS FROM PLANTS

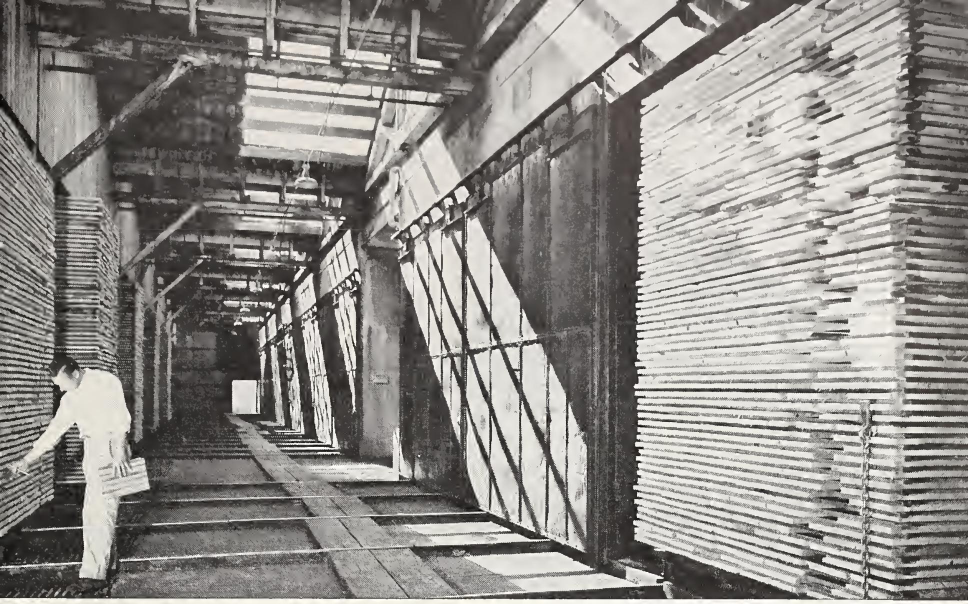
Lumber. Producing lumber is probably the oldest major industry in the United States. The first sawmill is reported to have been built about 1608 in Jamestown, Virginia, but even before that there are references to lumber from the New World in early books.

Trees and the lumber they produce can be divided into two main classes, the *softwoods* and the *hardwoods*. These names do not refer to the hardness of the wood, but to the type of tree. The softwoods are the trees commonly called evergreens, such as spruce, pine, and hemlock, and the wood from them. The hardwoods are oak, maple, basswood, and poplar, and their wood. The softwoods are used primarily for building, the hardwoods for furniture and interior finish.

The beauty and, to a large measure, the value of the finished lumber depend both upon the nature of the wood and the way it is sawed. *Annual rings,* which you can see on a cross section of a tree (page 298), give the wood one kind of grain; rays extending outward from the center of the log, especially in the hardwoods, give the lumber another kind of grain. By sawing the logs from end to end, a method called *plain sawing,* a grain satisfactory for many purposes can be produced. When it is desirable to give more prominence to the rays extending from the center outward to the edge of the log, *quarter sawing* is the method used.

After the logs have been sawed, the lumber must be dried or *seasoned* to remove most of its moisture. This is done in large ovens, called kilns (see page 591). Seasoned or *kiln-dried* lumber will not shrink or warp when used in buildings. Wood should always be treated with a material to preserve it. Transparent shellac, wax, or varnish allows the grain to show; paint covers the grain. Both kinds of material protect the wood so that it will last many years.

Wood for furniture. Wood used in making furniture is usually selected for its beauty. If the furniture is made throughout of only one kind of wood, it is called *solid:* solid oak or solid pine or solid mahogany. Such furniture is expensive, however; for that reason the practice of *veneering* was developed. In this a cheaper sturdy wood is used for the construction of the furniture, and a thin layer of beautifully grained wood is securely glued to it to give the appearance of a solid wood. Not only does this method produce less expen-



American Forest Products Industries

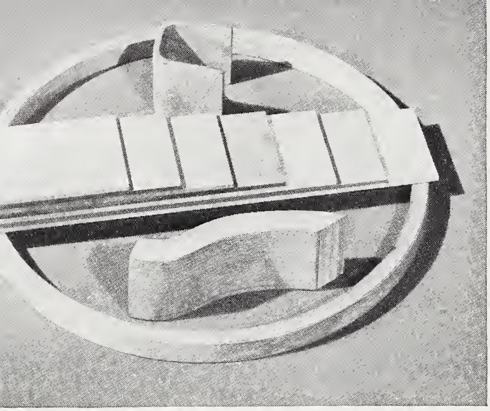
A kiln in which lumber is seasoned or dried. Note that the boards are stacked to allow air to circulate through the piles as well as over and under them.

sive but attractive furniture; it also helps to conserve the scarcer, more costly woods.

Paper. Millions of tons of paper are used in the United States every year for writing and printing, wrapping articles, shipping cartons, insulation, watertight containers, and a variety of other products. Most of the paper is made from wood pulp.

In the manufacture of paper, after the trees are cut, they are either hauled or floated down rivers to the paper mill. There the bark is removed and the logs cut into short lengths which are fed into a machine that cuts them into small chips. These chips are ground into fibers or are treated with chemicals which dissolve all the material in the wood except the fibers. Large machines through which the fibers are passed form them into sheets of paper of the desired size and thickness. To make white paper, the fibers are bleached with chemicals before being passed through the machine. Fine paper for printing or writing is coated with a material that keeps it from absorbing the ink used on it.

Other wood products. Logs can be put into machines that peel continuous sheets of thin slices of wood from them. By a process of gluing, these sheets are made into a strong building material called *plywood* (see page 592). Thin sheets of wood soaked in a chemical can be compressed into a material as dense and hard as many metals. It does not readily warp, split, shrink, or swell, and it can be dyed almost any color. It is used to make gears and small parts for machinery and other articles formerly made from metals.



American Forest Products Industries

Plywood is used for a variety of building purposes, such as in the manufacture of furniture, airplanes, and wall partitions. It can also be formed into unusual shapes, as shown above.

Shredded wood mixed with chemicals and pressed into large sheets is used in building. The smooth, hard surface, which can be painted or finished as wood is finished, makes it useful also in furniture making.

Cotton. Cotton plants grow best in a temperature of 70° F or higher, so most of the production in the United States is in the South. The cotton fibers, which surround the seeds of the plant, are of two kinds: one long, the other short. The longer fibers are made into strong, long-wearing cloth; the shorter ones make stuffing for mattresses and upholstered furniture. During World War II, cotton was the basis for more than 10,000 items of clothing, shelter, and fighting equipment for the armed forces.

Flax. The flax plant is probably one of the first plants used by man for its fibers. Most of the flax used for cloth fibers is grown in Russia, Holland, Belgium, and Ireland. The large quantities grown in the United States are used for the oil from its seed, known as *linseed oil.* To harvest flax for the fiber, the plant is usually pulled out of the earth, allowed to dry, and then bound into bundles. The bundles are later soaked in water, and the fibers extracted, cleaned, and woven into *linen* cloth.

Linen cloth is prized because of its fine even threads and its light weight. Because it absorbs moisture readily and releases it easily, linen is especially desirable for tablecloths, napkins, handkerchiefs, and various kinds of shirting, sheeting, and toweling.

Rubber. It is difficult to imagine how we could get along without products made from rubber. In automobiles alone there are more than twenty different uses of it; and it is also widely used in many other products such as tracks for tractors and trucks, bearings for the propeller shafts of ships, footwear, belts for machinery, hose, gloves, golf balls, and hundreds of other articles in daily use.

Natural rubber is obtained from a milky substance called *latex,* a product of rubber trees. Gathered as it flows from narrow grooves cut into the bark of the trees, the latex is then processed to produce crude rubber. This is mixed with sulfur and other substances which give rubber the properties required for so many different uses.

USES OF ANIMAL PRODUCTS

Animal hair. The hair of different animals is used in many ways. About 400 million pounds of sheep hair, called wool, are produced annually in the United States. Sheared from the sheep once each year, the wool is cleaned, straightened and sorted, spun into yarn, and then woven into cloth.

The structure of wool fiber is unusual. Because it is curly, it stretches easily, and can be spun into small, strong yarns which are soft and pliable. The small scales on the surface of the fibers lock together, adding strength to the yarn. When the fibers are pressed closely together into a heavy strong material called *felt,* the scales lock even more tightly together. Woolen cloth, with many dead air spaces between the curly fibers, is exceptionally warm, strong, and durable.

Horsehair is stiff and elastic and can be obtained in long strands. It is often used in clothing where stiffness will help a garment to keep its shape. The bows used to play instruments such as the violin are strung with horsehair, and it is also used as padding for some cushions and mattresses.

Silk. Prized for centuries because of its beauty, silk is produced by the silkworm, the larva of a moth, as it spins silk fiber into a cocoon. When the cocoon is finished, the silk fiber is unwound and spun into a thread which can be made into cloth.

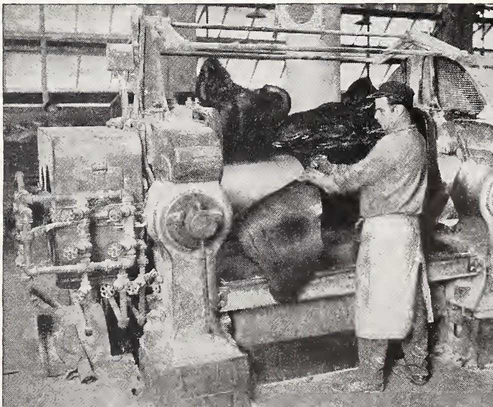
Pure silk, which is seldom seen, has a pearly luster. Since most people like silk to be bright and shiny, large amounts of chemical are added to the silk to give it this appearance. This process, called *adulteration,* causes the silk to lose much of its original tensile strength, leaving adulterated silk only one fifth as strong as pure unadulterated silk.

Leather. There are two general methods of preparing or *tanning* the skins of animals to produce leather. In both, flesh and hair are removed from the hides. In one method, the hides are soaked in a solution of vegetable materials obtained from oak, hemlock, or sumac bark containing a chemical called *tannin.* Then the skin, now leather, is finished to produce a smooth or rough surface and dyed the desired color. In the other method, a solution of chemicals other than tannin is used, and the leather so prepared is called *chrome-tanned* leather. If leather is painted with linseed oil varnish and baked to a high luster, patent leather is produced. Patent leather is used in making handbags, belts, shoes, and other articles.

The properties of leather made from different animal skins vary. Cowhide leather is suitable for shoes, harness, belting, and luggage; goatskin for some shoe and glove leather; while gloves and shoe linings are made from sheepskin. Chamois too may be made from sheepskin, although the best quality comes from the skin of an animal called a *chamois.* Leather made from the skins of the horse, pig, kangaroo, deer, alligator, peccary, seal, and walrus have different markings and are put to different uses.

An article made from the full thickness of leather is often labeled "genuine grain leather." This is the most expensive and best wearing kind. Thick hides are split to make "genuine split leather," which is cheaper, and does

In the process shown here, rubber is being mixed with certain chemical compounds. The addition of these chemicals helps give rubber the properties required when it is used for a great many different purposes.



not wear as well. Both types of leather are called genuine because they are obtained from the hides of animals. There are leather substitutes, however, which not only look like leather but wear almost as well as split leather and are less expensive.

SUMMARY

Wood can be processed into lumber for building purposes or manufactured into other materials used for a variety of purposes. The fibers of some plants and the hair of some animals are used in manufacturing cloth, as well as in a number of other materials useful to man. Leather products are made from the skins of animals.

TEST YOURSELF

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The terms hardwood and softwood, as applied to lumber, refer to the (a) hardness of the wood; (b) method of sawing the wood; (c) type of tree from which the lumber came; (d) length of time the lumber will last.
2. The practice of gluing a thin layer of expensive wood on a core of cheaper wood is known as (a) veneering; (b) kiln drying; (c) plain sawing; (d) seasoning.
3. The process of adding foreign material to silk is known as (a) tanning; (b) seasoning; (c) veneering; (d) adulteration.
4. Linen is obtained from (a) flax plants; (b) cotton plants; (c) trees; (d) animals.
5. If an article is made from the full thickness of leather it is often labeled (a) genuine split leather; (b) genuine grain leather; (c) patent leather; (d) chrome-tanned leather.

PROBLEM 2. How do we use materials obtained from the earth?

STONES AND METALS

Building stones. Natural stones, particularly granite, marble, and limestone, are taken from the earth and widely used in constructing buildings. Of these three, granite has the highest compressive strength. It is very hard and can take a high polish that will last many years. Marble can also be highly polished and often sparkles in the sunlight. In fact, the name *marble* came from a Greek word which means "sparkle." Because marble can withstand high temperatures without being damaged, it is often used in the construction of buildings designed to be fireproof. Limestone is the least expensive of the three building stones because it is most plentiful. It is found in all parts of the United States. Although it is neither as hard as granite nor as beautiful as marble, limestone is widely used because it is both substantial and cheap. Mixed with clay, heated, and ground into a fine powder, it becomes *cement*. When water and sand or gravel are added to it, cement hardens into *concrete*. Sandstone, soapstone, and slate are other natural stones used in buildings.

Metals. Metals are among the most important of the substances we use for making things. Most metals are durable and ductile enough to be formed easily into various shapes. They are also good conductors of both heat and electricity.

Metals differ rather widely in their weight, gold and platinum being among the heaviest. Gold is 19 times and platinum 22 times as heavy as water. Magnesium and aluminum are among the lightest metals. Magnesium is only 1.7 times as heavy as water, while aluminum is 2.7 times as heavy.

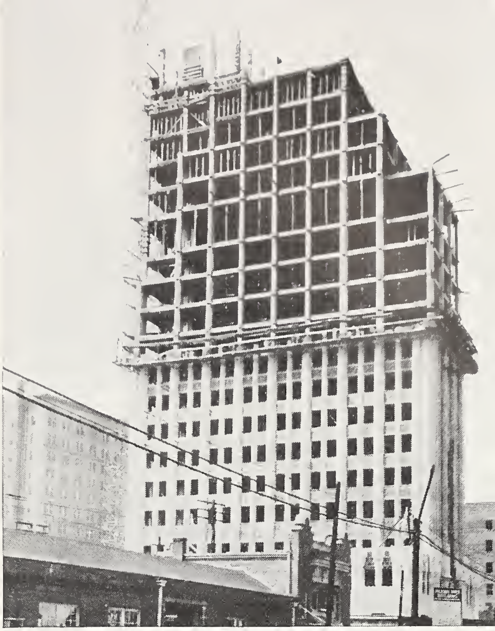
Extracting metals from ore. The method of getting a metal from its ore depends upon the elements with which it is combined in the ore. A great many metals are found combined with oxygen in the form of an oxide. Iron is usually obtained from such ores, known as *oxide* ores.

To obtain iron from its ore, the ore is mixed with coke and limestone and the mixture heated to a high temperature in a large blast furnace by a process known as *smelting*. The coke is used to separate the iron from the oxygen, while the limestone is used to remove the impurities from the ore. The overall chemical action taking place is represented by this equation:

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

The melted iron settles to the bottom of the furnace and is drawn off into rectangular molds, where it hardens. The hardened blocks are called "pigs." Once they are started, blast furnaces run continuously until they need repairs. Pig iron is also called cast iron.

Cast iron as it comes from the furnace is not malleable and can be used only for objects which can be molded. The cast iron is melted and poured into a mold of the desired shape; when the iron hardens, the mold is removed. However, if cast iron in the molds is heated to about 1350°F and allowed to remain at that temperature for two to three days, and then slowly cooled, a malleable cast iron is produced. The malleable cast iron has a tensile strength of about 35,000 pounds per square inch, and a 2-inch piece can be stretched from 2.5 to 7 per cent of its length without breaking, making it valuable for use in the manufacture of railroad equipment, farm machinery, pipe fittings, hardware, and tools of various kinds. More than one million tons of malleable cast iron are produced each year in the United States.



Reinforced concrete makes an excellent building material because it is strong, it can withstand exposure, and it is easy to use.

All cast iron, even the malleable

kind, is far more *brittle* than pure iron; that is, it breaks more easily when struck a sharp blow. It is brittle because of impurities in it. Chief among these impurities are carbon and silicon, with some sulfur, phosphorus, and manganese. When the cast iron is heated to a high temperature and mixed with oxygen from the air, the impurities combine with the oxygen and can be removed. A very ductile, malleable iron noted for its strength and toughness is left. It is called *wrought iron* and is used to make boilers, boiler tubes, screws, rivets, nails, and wire.

Sulfide ore. When a metal is found combined with sulfur, its ore is called a *sulfide* ore. A large amount of copper ore is found in this form.

The metal from a sulfide ore, such as copper, is obtained by carefully controlled oxidation in the presence of silica. The silica combines with impurities so that they can be readily separated from the copper. Although the oxidation takes place in several steps, the overall results are expressed by this equation:

$$Cu_2 + O_2 \longrightarrow 2Cu + SO_2$$

An impure copper, known as *matte,* results from the above oxidation.

The copper matte reaches the refining plant from the smelter in sheets about 3 feet square and 1 to 2 inches thick, weighing between 500 and 750 pounds each. The impure copper sheets, along with pure copper sheets the same size but only about $\frac{1}{16}$ to $\frac{1}{32}$ inch in thickness, are hung in large, lead-lined tanks filled with a solution of copper sulfate and sulfuric acid. The impure copper sheets are attached to the positive pole of a source of direct current, while the thin, pure copper sheets are attached to the negative pole. As electricity flows through the solution, it transfers copper from the impure sheet to the pure sheet. The impurities are not transferred. Copper refined by electricity is about 99.9 per cent pure. Electricity is also used in refining other metals, such as aluminum, zinc, and lead.

Pure copper is ductile and malleable. It is a good conductor of both heat and electricity, and it resists weathering. These properties make it very useful for electrical work and for use outdoors where weathering is to be avoided. Its color and malleability make it suitable for many ornamental uses.

Extracting metals from ores with electricity. It is extremely difficult, if not impossible, to remove some metals from their ores by smelting. Aluminum is one of these metals. Thus, even though small amounts of aluminum were produced as early as 1825, it was very costly. Napoleon once had table-

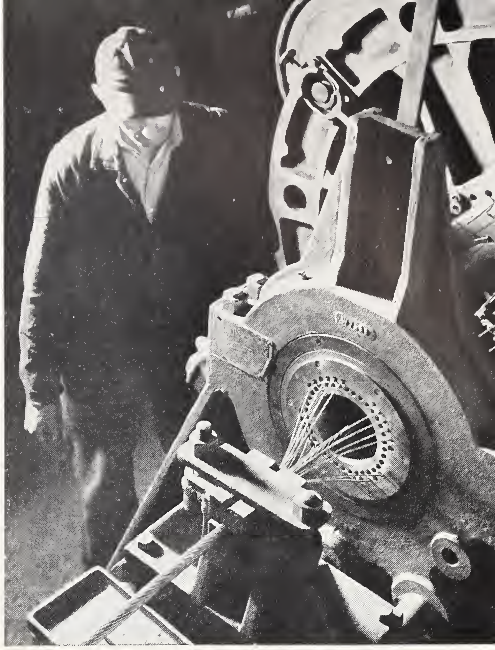
The workmen are filling specially-shaped molds with melted aluminum. After the aluminum hardens, the mold is removed and the solid aluminum is left in the desired shape.

Ewing Galloway

ware made from aluminum to use at state banquets because it was more costly than either gold or silver. In 1886 Charles Martin Hall, an American scientist, and Paul L. T. Heroult, a French scientist, each working individually, discovered a way to separate aluminum from its ore by using electricity. The process is known today as the Hall-Heroult process and is still used. The development of this process reduced the cost to less than 20 cents a pound, and made it one of the most widely used of all the metals.

Aluminum is one of the most abundant minerals in the earth's crust. However, *bauxite,* the only ore from which aluminum can be easily extracted, is less abundant. After the ore is mined, it is treated with chemicals to form a substance called alumina. The alumina is then dissolved in a melted mineral kept at a temperature of about 1800°F in a carbon-lined container. The carbon lining is attached to the negative terminal of a source of direct current, while some carbon rods that dip into the solution are connected to the positive terminal. As electricity flows through the solution, the aluminum falls to the bottom of the container. It is then drawn off into molds and hardens as cast aluminum. Aluminum-producing plants are usually located near hydroelectric plants, because they require large amounts of electricity.

Aluminum has some unusual properties that account for many of its uses. It is very light, yet has a tensile strength of about 4.5 tons per square inch. It is also quite elastic. As soon as aluminum is exposed to the air, it is covered with a very thin coating of oxide which protects it from further chemical action without taking away its luster. Because of its high luster, aluminum is a good reflector of radiant energy; it is also a reasonably good conductor of heat and electricity. Aluminum wires with a steel core added for strength are being used for electric power cables. Cooking utensils were among the first items made from aluminum, and much of it is still used for this purpose.



Ewing Galloway

Because of its ductility, aluminum can be drawn into wires. In this machine a number of aluminum wires are being twisted into a strong, light cable.

Metals from the sea. Man, in his never-ending search for new sources of metals, has turned to the sea, for in the oceans of the world there lies a fabulous wealth of materials. In every 100 pounds of sea water there are about 3½ pounds of chemicals.

Magnesium ranks eighth among the chemical elements found in the earth's surface, but gradually magnesium compounds have been dissolved by the waters of the rivers and washed into the sea. These compounds have become more and more concentrated as the water evaporated from the sea, until now there is one part of magnesium to 785 parts of sea water. Translated into tons, this means there are about 6,000,000 tons of magnesium in every cubic mile of sea water.

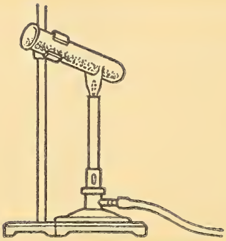
Not until 1941 was magnesium taken from sea water on a commercial scale. That year a chemical company opened a plant for extracting magnesium from sea water at Freeport, Texas. This plant can produce 9,000 tons of magnesium each year.

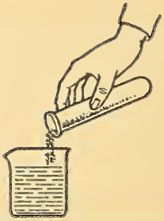
Magnesium is a light-weight, silver metal which in its pure form is of little value for constructing things. When mixed with other metals, however, it forms materials with properties highly desirable for constructing things.

SUMMARY

Whereas stone can be used in the form in which it is obtained from the earth, metals must be extracted from their ores before they can be used. Methods for obtaining metals from their ores depend upon chemical reactions to release the metal from the compounds in which it is found. After metals have been obtained from ores, they are treated so as to give them properties desirable for constructing things. The development of methods for extracting some of the materials from sea water has increased our available resources of these materials.

DEMONSTRATION





Generalization to be demonstrated. Metals can be separated from oxide ores by heating the ores with carbon.

What you need. Test tubes; copper oxide; powdered charcoal; ringstand; burette clamp; Bunsen burner; beaker of water.

What to do. Thoroughly mix a teaspoonful of copper oxide with an equal amount of powdered charcoal. Place the mixture in a test tube, and clamp the test tube in a nearly horizontal position, at the same time spreading the mixture evenly along the test tube. Heat the mixture strongly with the Bunsen burner until no further action takes place. After the tube has cooled, dump its contents into the beaker of water. Stir and pour off the lighter material. Examine the heavier material that remains in the beaker.

What to observe. Does the material remaining in the beaker look like copper?

What does it mean? Does the evidence you obtained tend to prove or disprove the generalization stated at the beginning of this demonstration?

Some basic assumptions in this demonstration. 1. The material remaining in the beaker is copper.

2. Other oxide ores will act as copper oxide did in this demonstration.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words which should be substituted for the italicized ones to make the statement true.

1. When limestone and clay are mixed together, heated, and ground into a fine powder they form *concrete*.
2. Some metals can be obtained from oxide ores if the ores are heated with *carbon*.
3. The purpose of heating a sulfide ore is to make the *oxide* turn into a *sulfide*.
4. Electricity is used in separating *aluminum* from its ore.
5. *Gold* is obtained in large amounts from sea water.

PROBLEM 3. How do we use synthetic materials?

SYNTHETIC FIBERS

As early as 1855 scientists, not content with existing materials, were experimenting in their laboratories trying to produce fibers to replace silk, cotton, flax, and wool. At least four types of synthetic fibers have been developed and are being quite generally used.

Rayon. Most rayon is made from fibers of wood or cotton. The plant fibers are dissolved by chemicals to form a thick liquid resembling syrup. Forced through a tiny hole into a special chemical solution, the thick liquid hardens into a thread that resembles silk, but is much thinner. One pound of rayon will make a single strand of fiber 2,500 miles long, while one pound of silk consists of a fiber only about 1,000 miles long.

Two kinds of rayon are manufactured. The fibers of one kind have the same chemical composition as the plant fibers from which they are made. This type of rayon when dry is slightly stronger than adulterated silk fibers and about twice as strong as a similar cotton fiber, but it loses tensile strength when it is wet. The loss in strength is caused by the absorption of water and a resulting swelling of the fibers. Because this type of rayon readily absorbs moisture, it is desirable for use as undergarments.

Although the second kind of rayon

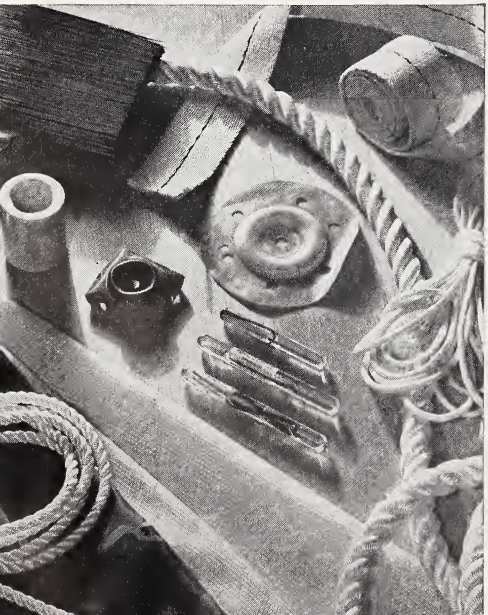
is also made from plant fibers, the process used in manufacture gives the fiber a different chemical composition. This rayon does not lose its strength when wet because it absorbs only a slight amount of water. This property makes it desirable to use for materials that must retain their tensile strength when wet.

Rayons are produced in three finishes: dull, semi-dull, and bright. Rayon is widely used for clothing of all types. The cords in many automobile tires are made from it, and because it has good insulating qualities, it is used as a wrapping for wire carrying electricity.

Nylon. Nylon came about almost by accident. Some American chemists were studying the process by which large molecules could be formed from smaller ones. One day one of the men noticed that some of the material they had developed could be pulled into long fibers. This observation started them working toward the production of a synthetic fiber. Nylon was the result.

A variety of products made of nylon are shown below. They include tapered bristles for a brush, various kinds of rope and webbing, a nylon plastic bearing, carburetor diaphragms, and "thread" for surgical stitches.

DuPont Company



There are really a great many kinds of nylon, all produced from basic materials such as coal, salt, natural gas, air, and water. By the special chemical processes developed, small molecules of these materials are combined in a way that produces the new material, nylon.

Vinyon. Natural gas and salt can also be converted into a fiber called *vinyon,* which has high tensile strength and will resist chemicals, molds, and damage from insects. Since it can be dyed all colors and makes beautiful cloth, vinyon can be used to make many types of articles from sheer hosiery to heavy cloth and felts.

Lanital. For many years scientists have known that one of the substances (*casein*) in milk is very similar in chemical composition to the fibers of wool. This fact led many of them to try to make a synthetic fiber resembling wool from milk. The problem was finally solved by an Italian scientist, Antonio Ferretti, who produced a synthetic fiber called lanital (a combination of two Italian words: *lana,* meaning "wool," and *Italia*), which differs only slightly from natural wool fiber. Lanital can be woven into cloth just as wool is and on the same machines, and the cloth is as warm as woolen cloth. When mixed with wool, it is very difficult for experts to tell the real wool from lanital.

Synthetic rubber. Rubber has become a necessity for modern living. The annual consumption of rubber and rubber products amounts to about 10 pounds per person each year in the United States. In spite of the huge amount consumed, almost no natural rubber is produced in the United States. This fact has stimulated attempts to produce synthetic rubber at low cost, especially during World War II. As a result, many types of synthetic rubber have been developed.

Although for a great many years scientists have tried to duplicate natural rubber in the laboratory, they have not yet been successful. However, many materials have been produced that can be stretched and yet return to their original shape in much the same way as rubber. Each of the various types of synthetic rubber has some property that makes it superior to natural rubber for certain uses even though for other uses it may be inferior.

ALLOYS

If two or more metals are mixed when they are melted and then allowed to harden, the resulting substance is called an *alloy*. Alloys are among the most important of the materials man uses. They were probably discovered about 1800 B.C. when a little tin was mixed with melted copper. The tin and copper hardened into a new material, bronze, superior to either tin or copper for making tools. It is still widely used today.

A tremendous number of alloys have been developed and new ones are being created each year. Some of the more common alloys together with their composition, properties, and uses are given in the table below.

Steel. Steel, an alloy of iron and carbon, is probably the most important of all alloys. Pig iron contains about 4 per cent carbon. In making steel, the 4 per cent of carbon contained in the iron is usually reduced by burning to less than 1 per cent. The resulting plain carbon steels are malleable, tough, and have high tensile strength. They have many thousands of uses, ranging from tiny needles to giant steel girders.

Small amounts of several different metals can be mixed with plain carbon steel to form alloy steels. The properties of these alloy steels depend upon the kind and the precise amount of metal mixed with the plain carbon steel. Some are resistant to corrosion, others

SOME COMMON ALLOYS

NAME	COMPOSITION	PROPERTIES	USES
Brass	Copper (66–73%) Zinc (34–27%)	Malleable and ductile	Sheets, tubes, wires
German silver	Copper (55%) Zinc (25%) Nickel (20%)	Hard; readily polished	Substitute for silver
White gold	Gold (90%) Palladium (10%)	Soft; does not tarnish easily	Coinage
Nickel coinage USA	Copper (75%) Nickel (25%)	Resists wear, does not tarnish easily	Coinage
Sterling silver	Silver (92.5%) Copper (7.5%)	High heat conductivity; harder than pure silver	Tableware

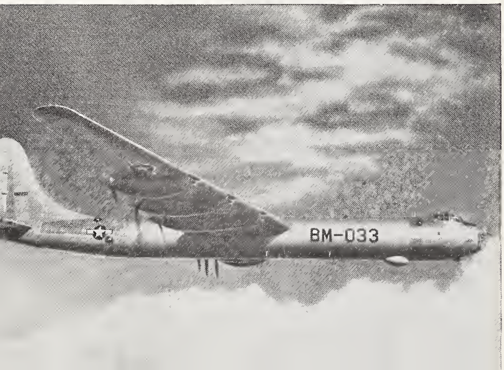
are hard yet elastic; still others are heat-resistant.

Light-weight alloys. One extremely important characteristic of some alloys is their light weight. The streamlined train or the bright plane you see flashing by are made possible largely by these light-weight alloys. Two such light alloys are mixtures of magnesium and aluminum. Wherever they are used, there is a great saving in weight without loss of strength. In one case, the funnel of an ocean steamer was reduced in weight from 8,000 to less than 3,000 pounds; the weight of a piano can be reduced by about 80 pounds by use of an aluminum alloy plate. Modern airplanes, buses, and streamlined trains would be from 10 to 25 per cent heavier if light-weight alloys were not used in their construction.

Powder metallurgy. Scientists have discovered that if metals such as copper, iron, and tin are made into a fine powder and pressed in a mold with many tons of pressure per square inch, the grains of powder will stick to each other to form an object the shape of the mold. If this object is then heated—but not enough to melt the metal—the particles stick firmly to each other to form a material that has properties fitting it for special uses. The process of making objects from metal powders is called *powder metallurgy*. The material is known as a *sintered alloy,* if powders of two or more metals are mixed together, or a *sintered metal,* if powder of only one metal is used. The word *sintered* describes the fact that the powder was heated—but not enough to melt the metal.

Without strong, light material, an airplane the size of this, with a wingspan of 230 feet, a length of 162 feet, and a height of 47 feet, would be impossible. This airplane has flown non-stop more than 10,000 miles.

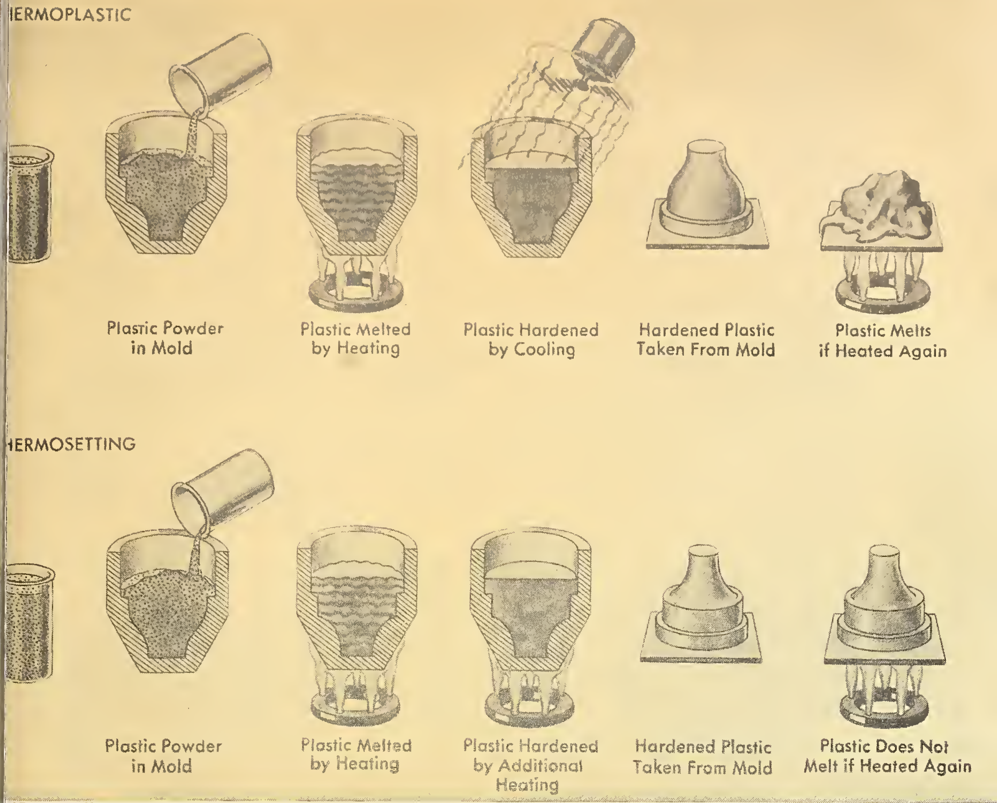
Consolidated Vultee Aircraft Corporation



Because of the way they are produced, sintered alloys or metals have a large number of tiny air pockets in them. The size and number of the air pockets can be varied by selecting the kind and size of the metal grains used and the amount of pressure placed upon them. If the pockets are small, the alloy may be used to make a self-lubricating bearing for use in machinery. Oil creeps into the metal as though it were a sponge and then is released to lubricate the machinery as needed. The metal can also be used as a selective filter, which will allow any water that collects in the gasoline tank of automobiles to run out through the filter, but does not allow the gasoline to flow out.

Since objects of sintered alloys are made by pressing the powder into molds, rapid and accurate production is possible. Making small parts for machinery by using sintered alloys or metals often results in a saving of 50 per cent or more in the cost of parts made.

Plastics. Almost everyone has some article made from a plastic. It may be a fountain pen, a raincoat, a piece of jewelry, or any one of a thousand other things. Plastics can be made any color


IERMOPLASTIC
Plastic Powder in Mold
Plastic Melted by Heating
Plastic Hardened by Cooling
Hardened Plastic Taken From Mold
Plastic Melts if Heated Again
IERMOSETTING
Plastic Powder in Mold
Plastic Melted by Heating
Plastic Hardened by Additional Heating
Hardened Plastic Taken From Mold
Plastic Does Not Melt if Heated Again

Comparison of the processes used in manufacturing thermoplastic and thermosetting plastics. This explains the different uses to which they are put.

or colorless. They can be made hard or soft, flexible or rigid, and in any shape desired. Plastics are among the most versatile materials man has yet developed. To make a plastic, materials usually in powder form are first mixed together. The powder is heated until it melts and fuses together to form a thick syrupy mass. Sometimes further heating of the syrupy material will cause it to harden permanently into a solid, called a *thermosetting* plastic. Such plastics are used for products to be subjected to high temperatures in their normal use, such as bakelite, electrical appliances, handles for cooking utensils, and switch plates for electric switches and outlets.

Plastics made by allowing the melted powder to harden by cooling are known as *thermoplastic*. Because these plastics soften each time they are heated, they cannot be used for products that need to be subjected to high temperatures. There are many uses for thermoplastics, however, among these being furniture, lenses for eyeglasses, clock dials, and crystals, enclosures for airplane cockpits, piano keys, and drafting instruments.

Silicones. About 1900 an English scientist, Professor F. S. Kipping of the University of Nottingham, succeeded in making a number of compounds of silicon that were unknown to scientists even though a large part of the earth's crust is made of silicon. Not until 1944 did scientists succeed in making these compounds in large quantities. They have been named *silicones.* Silicones, compounds of silicon, oxygen, and hydrogen, can be made either as liquids or solids. They are water-repellent, will not burn easily, and are little affected by changes in temperature. Silicones are also good electric insulators.

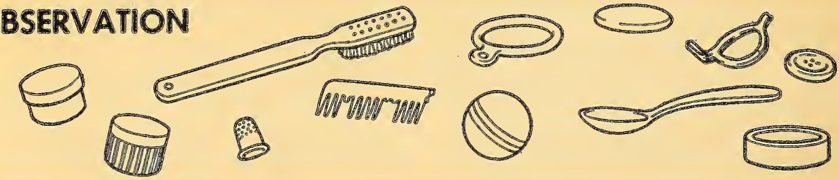
The ability of silicones to repel water makes them especially useful. Clothing sprayed with silicone is waterproof; creases in trousers remain unaffected by a shower. If the electric system of an engine is sprayed with silicone, it will continue to operate even when soaked with water.

Silicone oil will flow at low temperatures much better than ordinary oil, and will not be harmed by temperatures as high as 500°F. Silicone grease will lubricate properly at much higher temperatures than ordinary grease. A rubber made from silicone is similar to ordinary rubber except that it is unaffected by extreme temperature changes. Gaskets made from this rubber are used to seal lenses on spot lights when all other known materials fail because of the high operating temperatures. A piece of this rubber was still flexible after 24 hours in a temperature of 70°F below zero. A silicone insulating varnish has made it possible to increase the operating life of small electric motors.

SUMMARY

Scientists have produced a number of synthetic materials which have met some of our needs more effectively than many of the materials we previously used. These synthetic materials include new fibers, rubber, plain and sintered alloys, plastics, and silicones.

OBSERVATION



What to observe. The effect of heat upon some plastics.

How to observe it. Obtain a number of different small articles made from plastic, such as a toothbrush, a comb, lids for bottles. Place the articles in a beaker of water and heat them to the boiling point of the water. Examine the articles while they are hot. Which ones soften when heated?

Interpretation of your observation. Write one sentence stating the effect of heat upon some plastics.

TEST YOURSELF

If a statement is true, write the word *true* in the proper place on your answer sheet. If a statement is false, write the word or words which should be substituted for the italicized ones to make that statement a true one.

1. If a rayon fiber in process of manufacture is given a different chemical composition from the plant fiber from which it is made, the rayon fiber *will* lose tensile strength when it is wet.
2. The synthetic fiber which most closely resembles wool is *vinyon*.
3. If two or more metals are mixed when they are melted and then allowed to harden, the resulting substance is called an *alloy*.
4. *Bronze* is probably the most widely used of all alloys.
5. *Sintered* alloys are produced from powdered metals.
6. A *thermosetting* plastic will soften each time it is heated and will harden when it cools.

CHAPTER ACTIVITIES

REVIEW YOUR UNDERSTANDING

Three general classes of materials which man uses are listed below, followed by the names of a number of different materials. Beside the number of each material write, in the proper place on your answer sheet, the letter of the class to which that material belongs. **Do not write in your textbook.**

CLASSES OF MATERIALS

a. Materials from plants and animals
b. Materials from the earth
c. Synthetic materials

DIFFERENT MATERIALS

1. Steel
2. Copper
3. Lumber
4. Wool
5. Linen
6. Plastic
7. Aluminum
8. Leather
9. Rayon
10. Cotton
11. Lanital
12. Paper
13. Silicone
14. Plywood
15. Felt
16. Silk
17. Marble
18. Iron
19. Magnesium
20. Nylon
21. Rubber
22. Granite

ILLUSTRATE GENERALIZATIONS

Three important generalizations developed in this chapter are listed below. Beneath each generalization is a list of statements which may or may not illustrate the generalizations. On your answer sheet, beside the number of the generalization, write the letters of those statements which illustrate that generalization.

1. Plants and animals furnish man with many useful materials.
    a. Many homes are made from lumber.
    b. The age of a tree that has been cut down can be estimated by counting the number of annual rings in its stump.
    c. Felt is used in making hats.
    d. Cabinets are sometimes constructed from plywood.
    e. Magnesium is extracted from sea water.
    f. Some luggage is made of genuine grain leather.

2. The earth is a vast storehouse of materials useful to man.
  a. Napoleon once had tableware made from aluminum because it was more costly than gold or silver.
  b. Marble is sometimes used in fireproof buildings.
  c. Iron is separated from an oxide ore by smelting.
  d. Limestone is used in the construction of buildings.
  e. Many highways are concrete.
  f. The word *marble* comes from Greek meaning "sparkle."

3. Man has produced synthetic materials with more desirable properties than any of the known materials that occur naturally.
  a. Plant fibers are made into rayon that will make a single strand two and a half times longer than a silk strand.
  b. Coal, salt, natural gas, air, and water can be made into nylon.
  c. Steel is basically an alloy of iron and carbon.
  d. Most electric wiring is copper.
  e. Silicones are water repellent.
  f. Aluminum is a good conductor of heat.

UNIT ACTIVITIES

APPLY YOUR KNOWLEDGE

This test is divided into two parts. In each part, several of the properties which materials may possess are listed under A. A number of the uses made of materials are listed under B. In the proper place on your answer sheet, beside the letter of each use listed under B, write the number of the property under A that is most closely related to that use.

Part 1

A. PROPERTIES OF MATERIALS

1. Malleability
2. Hardness
3. Tensile strength
4. Melting point
5. Magnetic properties

B. USES OF MATERIALS

a. Supporting the roadway of a bridge
b. Wrapping candy with metal foil
c. Grinding tools
d. Pulling an elevator car
e. Making compass needles
f. Making containers to be used in a high-temperature furnace
g. Making metal sheets for automobile bodies
h. Sandpapering
i. Making ladles for handling melted steel
j. Making the core of a transformer

Part 2

A. PROPERTIES OF MATERIALS

1. Elasticity
2. Ductility
3. Resistance to chemical activity
4. Compressive strength
5. Thermal conductivity

B. USES OF MATERIALS

a. Making metal into wire

b. Making containers for holding acids
c. Making springs for automobiles
d. Supporting large buildings
e. Insulating walls of a house
f. Making watch springs
g. Making electric-light filaments
h. Making the core in an automobile radiator
i. Making runways for large airplanes

MAKE VISITS

1. A lumber yard to see what different constructional materials are available

2. A house under construction to see how different materials are being used

3. A factory where some product, such as clothing or household appliances, is being manufactured to find out how many different kinds of materials are being used

LEARN ABOUT USE OF MATERIALS

1. Make a list of the different kinds of materials in use in your home.

2. Make a list of the articles on some counter in the five- and ten-cent store, telling what materials were used to make them and why you believe those materials were selected.

3. Analyze the advertisements in a magazine and list the new and unusual uses for materials. Suggest why the materials have been used for the purposes indicated.

4. Write to an automobile factory to get a list of materials used in making an automobile.

REPORT ON USE OF MATERIALS

1. Manufacture and use of paint
2. Machines for testing materials
3. Manufacturing glass
4. Lumbering in the United States
5. Unusual alloys
6. The work of the National Bureau of Standards
7. Research laboratories in industry
8. The different kinds of steel
9. Production of natural silk

READ ABOUT USES OF MATERIALS

Bendick, Jeanne. *How Much and How Many.* New York: Whittlesey House, 1947.

The purpose and work of the National Bureau of Standards are explained on pages 163-172.

Burns, William S. *A World Full of Homes.* New York: McGraw-Hill Book Company, Inc., 1953.

The author reports on a remarkable range of ancient and modern dwellings.

Copper. Washington, D. C.: Pan American Union, 1952.

Popular account of properties, uses, and mining of copper.

Dearle, Denis A. *Opportunities in Plastics.* New York: Vocational Guidance Manuals, Inc., 1953.

Description of the major types of plastics, their preparation and use in industry, in addition to vocational opportunities in plastics.

Diamond, Freda. *Story of Glass.* New York: Harcourt, Brace and Company, Inc., 1953.

History of the manufacture and uses of glass. The author, a designer of glassware, emphasizes esthetic as well as utilitarian aspects.

Fisher, Harry L. *Rubber and Its Uses.* New York: Chemical Publishing Co., Inc., 1941.

Both natural and artificial rubber are considered in this book.

Hazard, Joseph T. *Our Living Forests.* Seattle: Superior Publishing Co., 1948.

The last part of this very interesting book deals with the ways in which wood from trees is used.

Hobbs, Douglas B. *Aluminum.* Milwaukee: The Bruce Publishing Co., 1938.

The first part of this book deals with the history of aluminum and modern manufacturing processes, and the second part describes 25 "projects" that amateur metal workers can make out of aluminum.

Lent, Henry B. *From Trees to Paper.* New York: The Macmillan Company, 1952.

This visit with the author to a paper company is instructive and enjoyable.

Leyson, Burr Watkins. *Plastics in the World of Tomorrow.* New York: E. P. Dutton & Company, Inc., 1944.

Describes the characteristics of the principal plastics and their uses.

Manchester, Harland. *New World of Machines.* New York: Random House, Inc., 1945.

Part III of this book deals with artificial rubber, plastics, and other new materials.

Mesa Miracle; in Colorado, Utah, New Mexico and Arizona. New York: Union Carbide and Carbon Corporation, 1952.

Story of mining and processing uranium ores.

Metcalfe, June M. *Copper.* New York: The Viking Press, 1946.

Includes the history of copper and describes the processes used in mining, refining, metallurgy, and manufacture.

Rogers, Matilda. *The First Book of Cotton.* New York: Franklin Watts, Inc., 1953.

This book relates how cotton is grown, how the crop is harvested, the operation of the cotton gin, the uses of cotton seeds, the manufacture of yarn and fabrics, the machines, the processes and the people who enter into this industry.

Schoener, Herman. *The Story Behind Steel.* New York: Alfred A. Knopf, 1944.

A description of the many processes involved in obtaining iron and manufacturing steel, our most important material for construction.

Strack, Lilian H. *Magnesium, A Magic Mineral.* New York: Harper & Brothers, 1943.

A fascinating story of magnesium and its alloys.

Strack, Lilian H. *Radium, A Magic Mineral.* New York: Harper & Brothers, 1941.

Describes the properties of radium, tells where it is found and how obtained, and some of the uses to which it is put.

What's a Silicone? Midland, Michigan: Dow Corning Corporation, 1952.

Experiences of customers with silicone products.

Wolfe, Bernard. *Plastics: What Everyone Should Know.* Indianapolis: The Bobbs-Merrill Company, 1945.

After reading this book you will wonder if anything is impossible in the plastic world.

Wright, Captain Bailey, Dyer, W. E., and Martin, Rex. *Flight: Construction and Maintenance.* Chicago: American Technical Society, 1942.

Two sections, "Woods Used in Airplane Construction" and "Metallurgy," include a great deal of information dealing with testing and selection of materials for airplane construction.

NO MORE WORLDS TO CONQUER?

IT has been reported that after Alexander the Great had conquered the world known to him, he wept bitterly because he knew of no more worlds to conquer. Although this may or may not be true, it does illustrate the idea that man seeks, and perhaps needs, the challenge of the unknown. The frontier, scientific as well as geographic, stimulates him to use his imagination and to put forth his greatest efforts.

For Professor Albert Einstein the frontier was the incomplete knowledge of the nature of the universe and how it functions. Stimulated by that frontier, he created a new concept of the universe and the relationship between the matter and energy it contains. This led to the release of atomic energy as a source of power for man to use as he wants. The health of thousands of people who might be attacked by disease is a frontier, the challenge of which Dr. Jonas Salk could not ignore. The elimination of polio promises to be one tangible result of Dr. Salk's response to that challenge. Certainly the lives of these men would have been different—and so would the world—if they had not shaped their careers to meet the challenge they saw.

Probably you have, at one time or another, thought about your future. "What kind of work am I interested in doing? What can I do to make the world a better place for my having lived in it?" you may have asked yourself. When your thoughts turn in that direction, remember that there are many frontiers still to be conquered and that new frontiers are constantly emerging. The frontiers in science fall into three groups.

FRONTIERS OF BASIC SCIENTIFIC RESEARCH

Research is someone's effort to answer questions and satisfy curiosity about something. Dr. Langmuir, who in 1932 was given the Nobel award for his outstanding research, puts it this way. "Perhaps my most deeply rooted hobby is to understand the mechanism of simple and familiar phenomena."[1] This attitude seems to be the springboard from which many men dive into the field of basic research.

Doing basic scientific research is not easy. To prepare for it, a person must pursue a long path of intensive study. He must become an expert in mathematics, reading, and writing, as well as in many scientific fields. He must train himself to become a logical, clear thinker, adept at solving problems. He must be convinced that the properly executed experiment is his most useful tool. He must be creative so that he can chart out new paths rather than follow the old, well-worn ones. Finally, he must have patience and the will to work hard, at times with no evidence of progress. But his curiosity persists and drives him on to overcome all obstacles as he seeks answers to satisfy his questions.

What are some of the frontiers in basic scientific research? Oddly enough, scientists know relatively little about man himself. How can the handful of chemicals of which his body is composed be organized into something as wonderful as the human body which possesses all the attributes of life? How does the brain work? Why do cells grow old and die? What factors are strongest in determining how people behave toward one another? Certainly this frontier offers many challenges to a research worker.

Another frontier for research is the nature of matter and energy. Exactly what is an atom? How are its parts fitted together? What makes its parts cling to each other so tenaciously that huge machines are required to break them apart? Why can radiant energy behave as it does? What are cosmic rays and where do they come from? These and hundreds of other questions need to be answered before man can fully understand the nature of matter and energy.

Still another frontier is the great universe of which the earth and man are seemingly only a tiny part. How large is the universe? Is it growing larger or is it growing smaller? Is there life on other planets? What is the nature of the forces and materials in space?

As you read those questions, have you wondered what possible value the answers might have? Possibly none that you can immediately recognize—except the satisfying of someone's curiosity. Yet the information gathered for that purpose may be what a scientist in the future will need to solve a problem. It could be your curiosity which will find an answer to a future challenge.

FRONTIERS OF APPLIED SCIENCE

Man can construct a mental picture of situations that he thinks would suit him better than those he now has. For example, even though you like your black and white television picture, you can't help thinking, "Wouldn't it be more fun watching the football game if the picture were in color?" That kind of dreaming can lead to someone's trying to bring the dream to life. In doing so, he can devise better things and more efficient ways of doing what he wants or needs to do. And man's desire to improve his environment is the father of applied science.

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[1] Hawkins, L. A. *The Story of General Electric Research,* p. 16. The General Electric Company, 1950.

Perhaps you feel that knowledge is valuable because of the use that can be made of it, rather than because it satisfies your curiosity and helps you know more. That is the point of view that results in applied science. The frontiers of this lie all about you. How can we provide safer, faster, cheaper transportation? How can we build more durable, more comfortable, and less expensive homes? How can man's health be improved and his life span lengthened? How can we increase the productivity of the land on which crops are grown? As you saw, the challenge of basic research is to discover some new knowledge for man's benefit.

The same abilities and skills are needed for the applied scientist as for the basic research scientist. The chief difference between the two fields is their different emphasis. Behind almost every improvement in our lives lies someone's acceptance of the challenge of applied science. Yours may lead the way to a challenge as yet unknown.

FRONTIERS OF SCIENTIFIC CITIZENSHIP

Although you may not have thought of it in this way, the frontiers of good citizenship present some of the most significant challenges facing mankind. One of the reasons they are so important is that they are so universal. Most of you will not seek a career in basic scientific research or in applied science. But all of you will be citizens. Thus these frontiers and their challenges lie before each of you.

What are some of these frontiers? Basic scientific research is becoming very costly. The facilities required are extensive, the tools complicated and expensive. Only governments, large universities and colleges, and large industrial concerns are able to finance much of it. Futhermore, the training period for the research scientist is long, arduous, and expensive. How can the free curiosity which is the starting point of basic scientific research be best fostered in tomorrow's world? The citizens of a free, democratic society will have a voice in deciding what will be done.

As you have seen, the results of research and applied science are all around you. The airplanes, automobiles, houses, chemicals, household appliances, power-producing machinery are concrete examples of those results, which can be used for the good of mankind. One of the continuing challenges faced by every citizen, is to insure that the results will be used as intended, to help mankind. Certainly there is a frontier that challenges everyone today and will continue to do so in the future on matters as yet undreamed of. Your own imagination may be the stimulus to improving the lives of people everywhere.

Glossary

Because new science words are thoroughly defined and developed in the text, it has been possible to limit this Glossary to those words infrequently used or especially abstract or difficult. The Index not only shows how to pronounce these and other words, but also indicates by **bold face figures** the pages where science words are introduced and defined.

The following system of indicating pronunciation is used: ăct, āble, dâre, ärt; ĕbb, ēqual; ĭf, īce; hŏt, ōver, ôrder, oil, bo͝ok, o͞oze, out; ŭp, ūse, ûrge; ə = a in alone; ch, chief; g, give; ng, ring; sh, shoe; th, thin; t͟h, that; zh, vision.

absolute humidity (ăb′sə lo͞ot hū mĭd′ ə tĭ): the actual amount of water vapor in the air at any one time

air mass: a large body of air having about the same temperature throughout

alkali (ăl′kə lī′): a chemical substance which combines with other substances to form salts or soap; or changes the color of certain chemical indicators

alloy (ăl′oi): a mixture or combination of two or more metals

alpha ray (ăl′fə rā): a stream of particles issuing at high speed from certain radioactive substances

altitude (ăl′tə tūd′): the distance above sea level; also the distance of a star above the horizon

ameba (ə mē′bə): a one-celled animal having no fixed shape

ampere (ăm′pĭr): a unit used in measuring electric current

amplitude (ăm′plə tūd′): the extent of the action of a wave in opposite directions from a central position

amplitude modulation (ăm′plə tūd′ mŏj′ə lā′shən): a type of radio broadcasting in which the sounds change the strength (amplitude) of the carrier wave

antibiotics (ăn′tĭ bī ŏt′ĭks): substances produced by microorganisms that will kill or hinder the growth of other organisms

antibodies (ăn′tĭ bŏd′ĭz): chemical substances produced by cells of the body which counteract harmful materials that get into the body

armature (är′mə chər): the rotating core in a generator or motor

artificial respiration (är′tə fĭsh′əl rĕs′pə rā′shən): helping a person who has stopped breathing to get air into his lungs by mechanical manipulation

astigmatism (ə stĭg′mə tĭz′əm): defect of the eye which prevents sharp focus of images on the retina

astrologer (ə strŏl′ə jər): a person who studies the stars for the purpose of predicting events

atmospheric pressure (ăt′məs fĕr′ĭk prĕsh′ər): the pressure or push produced by molecules making up the air

atom (ăt′əm): the smallest part of a chemical element which still retains its properties

atomic (ə tŏm′ĭk) **energy:** the capacity for doing work possessed by the nucleus of an atom

atomic pile: the structure within which a chain reaction can be produced to release energy

bacterium (băk tĭr′i əm); plural, **bacteria** (-ĭ ə): tiny one-celled plant

balance of nature: a condition in which each type of living thing in a locality continues to exist in about the same number

beta ray (bā′tə rā): a stream of particles issuing at high speed from certain radioactive substances

British thermal (thûr′məl) **unit:** the amount of heat required to raise 1 pound of water 1°F

buoyancy (boi′ən sĭ): an upward force exerted by a fluid on any object floating on or submerged in it

calorie (kăl′ə rĭ): the large Calorie (Cal.) is the amount of heat required to raise the temperature of 1 kilogram of water 1°C; the small calorie (cal.) is 1/1000 of the Cal.

capacitor (kə păs′ə tər): a device made of two metal plates separated by an insulator, used for storing electric energy

capillary (kăp′ə lĕr′ĭ): a thin-walled blood vessel through which food, oxygen, and waste materials may pass to and from the blood

carbohydrate (kär′bō hī′drāt): a type of nutrient obtained from food, used to produce energy, or stored as fat in the body

carrier (kăr′ĭ ər) **wave:** a radio wave which can be changed by speech and music, thus carrying them to the listener

cathode ray (kăth′ōd rā) **tube:** an electron tube with one face coated with a material that fluoresces when struck with electron beams; often called a **kinescope** in a television receiver

cell: the smallest unit of a living thing; also used in referring to the unit of an electric battery

centrifugal (sĕn trĭf′yə gəl) **force:** a force which tends to make a whirling object fly outward from the center

chain reaction: an action that produces more energy than it uses and can thus sustain itself as long as the reacting substances are available

channel: in television, a band of frequencies 6 megacycles wide that is needed for broadcasting picture and sound signals sent out from the television transmitter

chemical energy: the capacity for doing work possessed by a substance because of its chemical structure

chemotherapy (kĕm′ō thĕr′ə pĭ): the treatment of diseases by use of chemical substances such as penicillin

chlorophyll (klō′rə fĭl): green coloring matter in plants

circuit (sûr′kĭt): a path provided for electricity to follow

cold front: that part of a front where colder air replaces warmer air at the ground

combustion (kəm bŭs′chən): oxidation rapid enough to produce large increases of heat and sometimes light

commutator (kŏm′yə tā′tər): a device used on an electric generator so that direct current can be obtained from it

compound (kŏm′pound): a chemical substance made up of two or more different elements

concave (kŏn kāv′) **lens:** transparent material with a curved surface, shaped so that it is thicker at the edge than through the center

conduction (kən dŭk′shən): the process of transferring heat through molecular contact

constellation (kŏn′stə lā′shən): a group of stars which form some recognized pattern in the sky

convection (kən vĕk′shən): the process of transferring heat with currents in a fluid such as water, or in air

convex (kŏn vĕks′) **lens:** transparent material with a curved surface, shaped so that it is thicker through the center than at the edge

crop rotation (krŏp rō tā′shən) the practice of changing crops that are grown in one field from year to year

cross-breeding: the practice of using a male and a female with different inherited characters to reproduce young

cyclone (sī′klōn): often used to mean a low, but also used in referring to any violent wind storm

cyclotron (sī′klə trŏn′): a device for increasing the speed of particles used to bombard the nuclei of atoms

decibel (dĕs′ə bĕl): a unit for measuring the intensity of sound

deficiency (dĭ fĭsh′ən sĭ) **disease:** a disease caused by lack of proper nutrients

density (dĕn′sə tĭ): the weight of a material expressed in grams per cubic centimeter or pounds per cubic foot

diastrophism (dī ăs′trə fĭz′əm): movements of the earth's crust causing vertical or horizontal changes in position as well as deformation of rocks

drag: resistance offered by the air to the forward motion of an airplane

ductility (dŭk tĭl′ĭ tĭ): the property of a material making it possible to draw it into fine wires

efficiency (ĭ fĭsh′ən sĭ): in science, the ratio of the work obtained from a simple machine to the work put into it

egg: the female reproductive cell which when fertilized develops into a new individual

elasticity (ĭ lăs′tĭs′ə tĭ): the extent to which a material resists being stretched, compressed, or twisted out of shape before it is permanently deformed

electric field: the space in which an electric force exists

electromagnet (ĭ lĕk′trō măg′nĭt): a device which becomes a magnet when electricity passes through it

electromagnetic (ĭ lĕk′trō măg nĕt′ĭk) **waves:** a combination of electric and magnetic fields that travel through space at about 186,000 miles per second

electromotive (i lĕk′trə mō′tĭv) **force:** amount of energy applied to cause electrons to move and produce an electric current in a conductor

electron (ĭ lĕk′trŏn): a part of an atom which swings about the nucleus; it has a negative charge

electron microscope (ĭ lĕk′trŏn mī′krə skōp′): a microscope in which electrons are used to observe things which could not be seen with visible light

electron (ĭ lĕk′trŏn) **tube:** a device for the control of electrons as they pass from one conductor to another through a vacuum or a gas

element: the smallest unit that combines with other such units in the formation of chemical compounds

embryo (ĕm′brĭ ō): a young plant or animal before it is completely formed

energy (ĕn′ər jĭ): the capacity for exerting a force through a distance and thus doing work

evaporation (ĭ văp′ə rā′shən): the process by which a substance such as water is changed into a vapor or gas

fertilization (fûr′tə lə zā′shən): union of the male and female reproductive cells

fission (fĭsh′ən): in atomic energy, the process whereby an atom splits into two parts; in biology, the process whereby microorganisms multiply by cell division

fluorescent (flo͞o′ə rĕs′ənt): pertaining to anything that will give off light (fluoresce) when exposed to ultraviolet or other types of radiant energy

focus, in focus: a sharp, clear image formed by a lens or mirror

foot-candle: a unit for measuring the amount of illumination from a light source

foot-pound: a unit for measuring work

force: a pull or a push exerted by something

frequency (frē′kwən sĭ): the number of cycles occurring in a second

frequency modulation (FM) (frē′kwən sĭ mŏj′ə lā′shən): a type of radio broadcasting in which the sounds change the frequency of the carrier wave

front: the surface of air separating a cold air mass from a warm air mass

fusion (fū′zhən): the process of releasing atomic energy by forcing simple atoms to combine into more complex ones with some of their mass being changed into energy

gamma ray (găm′ə rā): a type of radiant energy issuing from certain radioactive substances

gas: a substance that has no definite volume and spreads out to fill any container in which it is held

Geiger (gī′gər) **counter:** an electronic device for detecting radioactivity

germination (jûr′mə nā′shən): growth of the embryonic plant after the seed has been formed

gland: a part of the body that produces a chemical substance which aids in carrying on a certain function of the body

grafting: attaching a part of one plant onto another in such a manner that it will grow

gravity (grăv′ə tĭ): a force exerted by bodies because of the matter they contain, which tends to draw them closer together

helicopter (hĕl′ə kŏp′tər): an airplane with mechanically-driven rotating wings that furnish both the lift and driving force for the airplane

hemoglobin (hē′mə glō′bĭn): the substance in red blood cells with which oxygen combines

heredity (hĭ rĕd′ə tĭ): the process by which characters are passed on from parents to offspring

hormones (hôr′mōnz): chemical substance produced by special glands in the body which control certain body activities

horsepower: a unit for measuring power, equal to 33,000 foot-pounds per minute

humus (hū′məs): decayed organic matter in the soil

hybrid (hī′brĭd): the offspring produced by crossing two pure-line parents which are unlike in a particular character

hydroponics (hī′drə pŏn′ĭks): the practice of growing plants without soil

hypothesis (hī pŏth′ə sĭs): a temporary explanation of why or how something happens which may be tested later

illiterates (ĭ lĭt′ər ĭts): people who can neither read nor write

inbreeding: the practice of using two parents with the same characters to produce offspring

inertia (ĭn ûr′shə): the tendency of any object to continue to move once it is in motion or to remain at rest once it has stopped moving

infrared (ĭn′frə rĕd) **rays:** a type of radiant energy found in sunlight and re leased from any warm or hot object

inorganic (ĭn′ôr găn′ĭk) **matter:** substance formed from non-living things

invertebrates (ĭn vûr′tə brĭtz): animals without backbones

ion (ī′ən): an electrically charged particle, often formed in a gas

jet stream: a band of high-velocity wind that blows at very high altitudes

kilowatt (kĭl′ə wŏt′) **hours:** a unit for measuring both the amount and the rate at which electricity is used

kinetic (kĭ nĕt′ĭk) **energy:** the capacity for doing work possessed by a substance because of its motion

lift: in an airplane, the force which raises the airplane from the earth and holds it in flight

light-year: distance that light will travel in one year

liquid: a substance that has a definite volume but takes the shape of the container holding it

longitude (lŏn′jə tūd′): the distance east or west of a meridian expressed in degrees of time

loran (lō′rən): a system of long range navigation depending upon the use of radio waves

lymph (lĭmf): a colorless fluid which aids in transporting materials in the body

magnetic (măg nĕt′ĭk) **field:** the space in which a magnetic force, such as that around a magnet, exists

mechanical advantage: the ratio of the force obtained from a simple machine to the force used on it

mechanical energy: the capacity for doing work through machines

media (mē′dĭ ə): the material within which living things like bacteria will grow

meridian (mə rĭd′ĭ ən): an imaginary circle around the earth which passes through both the North and South Poles

meter (mē′tər): a unit of linear measure in the metric system equal to 39.37 inches; also a device for measuring such things as electricity and water

microwave (mī′krō wāv′): a radio wave with a high frequency and short wave length

millibar (mĭl′ə bär): a unit of measure of atmospheric pressure used on weather maps; 1050 millibars equal 31 inches of mercury on a barometer

millimicron (mĭl′ə mī′krŏn): a very small unit for measuring length. It is one billionth (1/1,000,000,000) of a meter

molecule (mŏl′ə kūl): the tiniest part of a substance which still maintains the properties of the substance

mutation (mū tā′shən): a character, not inherited, possessed by plant or animal, which can be passed on to offspring

narcotic (när kŏt′ĭk) **drugs:** drugs which have a numbing effect on the body, such as opium

natural selection: the process whereby some groups of plants and animals are better fitted to survive because of their inherited characters

nebulae (nĕb′yə lē′): clouds of gases in outer space that glow from the light of stars that lie within or near them

negative charge: an excess of electrons which produces an electric field similar to that of a rubber rod rubbed with fur

neutron (nū′trŏn): a part of the nucleus of an atom

nucleus (nū′klĭ əs): a small body within a living plant or animal cell that controls many of the cell's activities; also, the central part or core of an atom

numerical weather prediction: the use of computing machines to obtain solutions to problems which can then be used in predicting weather

nutrients (nū′trĭ əntz): food substances that supply the body with energy, materials for growth, or with chemical regulators

ohm (ōm): a unit for measuring the resistance to electricity of a material

orbit (ôr′bĭt): a path in space along which a heavenly body moves around its center of attraction

organic (ôr găn′ĭk) **matter:** substances that are a part of, or come from, anything that has life

osmosis (ŏz mō′sĭs): the passage of liquids or substances in solution through a membrane

ovary (ō′və rĭ): the organ in plants or animals that produces eggs

overtone: vibrations which are small whole-number multiples of the lowest frequency contained in a musical tone

parallels of latitude (păr′ə lĕls ŏv lăt′ə tūd′): imaginary circles around the earth with all points on any one circle equal distances from (parallel to) the equator

parasite (păr′ə sīt): a plant or animal that lives in or on another living thing

phases of the moon: the different shapes through which the moon appears to pass in changing from new to full moon

photosynthesis (fō′tə sĭn′thə sĭs): the process in green plants of using light as energy in making food

pitch: the highness or lowness of a sound determined largely by its frequency

plasma (plăz′mə): the liquid portion of the blood

pollination (pŏl′ə nā′shən): the transfer of pollen from the male part of the flower to the female part

positive charge: a lack of electrons which produces an electric field similar to that of a glass rod rubbed with silk

potential (pə tĕn′shəl) **energy:** the capacity for doing work which does not show itself except under proper conditions

power: the rate at which work is done

proton (prō′tŏn): a part of the nucleus of an atom having a positive charge

precipitation (prĭ sĭp′ə tā′shən): water that falls to the earth as rain, snow or hail

prism (prĭz′əm): a piece of glass with three or more faces that will break white light which passes through it into its various colors

protoplasm (prō′tə plăz əm): the basic, living substance in all cells

protozoa (prō′tə zōə): single-celled animals such as the ameba

quantum (kwŏn′təm): a tiny bit of radiant energy released by an atom when one of its electrons falls from an outer to an inner orbit

radar (rā′där): a device used to discover and determine the position of objects by means of radio waves

radiant energy: energy such as light and radio waves that can travel through space

radiation (rā′dĭ ā′shən): the process of losing heat by giving off radiant energy

radioactivity (rā′dĭ ō ăk tĭv′ə tĭ): the process by which a substance spontaneously changes to another substance, releasing energy

radio beam: a radio signal by which a pilot can guide his plane along a path

reflection (rĭ flĕk′shən): the turning back of radiant energy from objects

reforestation (rē′fôr ĭst ā′shən): planting trees where forests used to be

refraction (rĭ frăk′shən): bending of light rays when they pass through substances of different density

relative humidity (rĕl′ə tĭv hū mĭd′ətĭ): a comparison of the amount of water vapor in the air with the total amount the air could hold at its temperature

revolution (rĕv′ə lo͞o′shən): a complete movement of a body around some fixed point

rotation (rōtā′shən): a turning action, as the earth turning on its axis

seedlings (sēd′lĭngz): young plants grown from seed

sexual reproduction: reproduction resulting from the union of a male and a female sex cell

shoran (shōr′ən): a system of short range navigation depending upon the use of radio waves

sky wave: a radio wave that travels upward from the transmitter antenna toward the sky

solar system (sō′lər sĭs′təm): the sun and all the bodies that revolve around it

solid: a substance that has its own size and shape

sound wave: alternating high and low air pressures which travel outward from a vibrating object

space wave: a radio wave that travels from the transmitter antenna through space, near the surface of the earth

spectroscope (spĕk′trə skōp′): an instrument which divides radiant energy such as light into its different wave lengths

spectrum (spĕk′trəm): the band of color from violet to red observed when white light is passed through a triangular-shaped piece of glass

sperm nucleus (spûrm nū′klĭ əs): the tiny body formed in the pollen tube that fertilizes the egg in the ovule

static electricity (stăt′ĭk ĭ lĕk′trĭs′ətĭ): a stationary electric charge

sterile (stĕr′ĭl): anything that has nothing alive in it or on it

supersonic (so͞o′pər sŏn′ĭk) **speed:** speed that is faster than sound

surface ground wave: radio wave that travels outward from the transmitter antenna through the surface of the earth

temperature: a measure of the hotness or coldness of a substance in relation to the freezing and boiling point of water

tissue: a group of similar cells doing the same kind of work, such as muscle

torque (tôrk): in a machine the product of a force by its perpendicular distance to the fulcrum, thereby being a measure of the rotational effect of the force

turbine (tûr′bĭn): an engine consisting of a cupped or vaned wheel made to rotate by the force of some fluid, such as water or steam, directed against the wheel

ultraviolet (ŭl′trə vī′ə lĭt) **ray:** a type of radiant energy found in sunlight and produced by specially designed lamps

vertebrates (vûr′tə brāts): animals with backbones

virus (vī′rəs): disease-producer too small to be seen by ordinary microscopes

volt: a unit for measuring the electromotive force

warm front: that portion of a front between warm and cold air masses where warm air replaces cold air at the ground

water table: an imaginary line at the highest level of ground water

wave cycle: a complete set of actions through which any wave passes before any particular action is repeated

wave frequency (frē′kwən sī): the number of cycles a wave completes in one second of time

wave length: the distance a wave travels while completing one cycle

water vapor: molecules of water containing sufficient heat energy to exist as a gas

work: the result of a force acting through a distance

X-rays: a type of radiant energy produced by special electron tubes

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